A TEXT-BOOK OF PRACTICAL ENTOMOLOGY

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BY

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PREFACE

THIS book started in the Zoological Department of the University of Cambridge as a number of loose sheets, issued from day to day to those taking the Entomology Course, by whom the sheets were irreverently described as the "daily mail." These early classes were composed of students who had already passed Part I of the Natural Science Tripos and were proceeding to Part II, so that what is now Part I of this book was then in a very abridged form and was only used for "revision work." Part III was first produced as a course for those students, already with an elementary knowledge of Entomology, intending to take it up as a profession, but, both it and Part I, were greatly modified and developed when I went to the Imperial College and elaborated a year's course of training for those applying for Colonial posts in Economic Entomology.

My object in building up the course has been, first, to let the student see as much as possible of the structure of the insect and of the modifications of those structures, but, at the same time, to understand how the various parts work.

I have, however, kept in mind that many of my students may be taking the course merely because it comes in the syllabus of work which they have to get through, and I have tried, therefore, to make it educational, not in the sense in which this word is so frequently misused, but as a training in method and neatness.

In the days of my own apprenticeship no attempt was made to *teach* the systematic side of the subject, the student being given boxes full of insects and Dr. Sharp's volumes of the *Cambridge Natural History* and being told to "go ahead." I think that I should adopt that method if it were necessary to dissuade anyone from continuing the study of Entomology, but it took me some time and some experimenting before I devised Part III of this book, which, I think my students would admit, is a painless and even an entertaining method of absorbing the principles of Systematic Entomology.

I am greatly indebted to successive classes of students, both at Cambridge and at the Imperial College, for useful criticisms which have led to various changes in the original sheets, and I am also very grateful to my old friend and quondam chief, Professor J. Stanley Gardiner, F.R.S., for encouragement and advice in the early days of my entomological teaching. I must also acknowledge the help of my friend, Dr. R. H. Whitehouse, who read through the typescript and dissected some of the types and made many useful suggestions,

and of my son, Mr. J. Balfour-Browne who, fresh from the second part of the Zoological Tripos, has given me advice on several points, advice which I have humbly accepted. Miss K. E. Burnand has helped me, both in typing the various editions of the MSS. and in reading through the proofs, and to her I express my gratitude.

FRANK BALFOUR-BROWNE

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PART III

THE PRINCIPLES OF SYSTEMATIC ENTOMOLOGY

A TEXT-BOOK OF PRACTICAL ENTOMOLOGY

INTRODUCTION

IN the work outlined in the following pages, the materials suggested are, as far as possible, those which can be easily obtained, either by collecting or from those who sell natural history specimens. Large grasshoppers and also cicadas can be bought ready for dissection from certain American dealers, for instance, Ward's Natural Science Establishment, College Avenue, Rochester, New York.

The book is divided into three parts corresponding to the three terms in a year's work, and, at the end of each part is given a time schedule showing the number of hours to be devoted to each subject in order to get through the course in the time allowed. These schedules are based upon a long experience both at Cambridge and at the Imperial College, London, but, in order to carry through all the work it will be necessary to provide the student with a number of microscope slides instead of leaving him to mount all the materials for himself. In my department I had a large collection of numbered slides, and those required for the subject were laid out on a tray in the laboratory each day. With them was a note indicating the use to be made of them, thus: "Slides showing typical mandibulate mouth-parts, Nos. 97, 98, 105, 493, etc. . . ." "Slides showing the proventriculus, Nos. 276, 278, 763, 937, etc. . . ." This system not only makes it easy for the student to pick out the correct slides, but it enables the teacher to find the necessary slides each time the course is given.

It is always best, where possible, to dissect freshly killed specimens, and that is the only reason why the cockroach has become the standard insect-type in all Zoology Courses in this country! If, however, fresh material is not available, specimens killed in boiling water, and boiled for several minutes (or killed in fixing solutions, such as Carnoy), and preserved in 70 per cent. alcohol will usually dissect quite nicely, especially if, preparatory to dissection, they are soaked for a few hours in warm, not hot, water: i.e. water at about the temperature of a paraffin bath. It is even possible to dissect specimens which have been dried and preserved in collections. By boiling these in strong potash or soda they can be restored to a condition in which a great deal of the

internal structure can be examined. Boiling for five minutes, in the case of a beetle, *Acilius sulcatus*, which had been dry for thirty-five years, made it possible to expand the ovipositor in a female specimen and the ædeagophore in a male and to trace the genital duct from the body into the armature. The stomodæum and the proctodæum were easily dissected out complete, and various other structures were in a satisfactory condition.

There is considerable art in using potash, and it will frequently be found in the following pages that instructions are given to boil in strong potash. Boiling in potash, like cooking, can be either underdone or overdone, and only experience can decide how far to go with a specimen; but excessive clearing is often a great mistake.

In Part I, the description of the Cockroach and also the drawings are from the species *Blatta* (*Periplaneta*) *americana*, except for one or two additional drawings of the more simple earwig. In Part II, the description of Dytiscus is from the species *D. marginalis*, but the drawings are not always from that species nor even from a species of that genus. In Part III, although the descriptions are from British species (excepting the Cicada), the drawings are often from others, and this has been done with intention. The student, like most of mankind, will usually take the easiest way, and it is much easier to copy the drawings than to make them from the specimens.

Although care has been taken to see that the script is correct for whatever species has been used for the drawings, there are frequently small differences between the British species and that from which my drawings have been made, so that it behoves the student to study his specimen rather than to rely upon my drawings. Moreover, many of my drawings are purposely diagrammatic rather than strictly accurate.

From what has been said, it will be clear that the notes can be used with types other than those specified, but it would be advisable for the supervisor to make himself acquainted beforehand with the species he provides, in order to see that it comes within the description given in these notes.

PART I

ELEMENTARY COURSE

I. THE GENERAL STRUCTURE OF THE INSECT

As shown in the Cockroach, *Blatta americana*

(For external characters, the common earwig, *Forficula auricularia*, has certain advantages in that the thoracic pleural and sternal sclerites are more easily made out, the large coxæ of the cockroach having somewhat altered the more primitive arrangement. For this reason, one or two drawings of the earwig are included.)

THE COCKROACH (*Blatta americana*)

Note. This species is larger than the usual house cockroach, *B. orientalis*, which, however, differs but little and can be used with these notes.

The insect provided belongs to the Order Orthoptera because:

1. It has "mandibulate" mouth-parts, i.e. mouth-parts adapted for biting and chewing.

2. It has wings in which the main "veins" are straight (hence the name Orthoptera, meaning straight-wings) and the hind-wings fold fanwise.

3. It has "incomplete metamorphosis," i.e. the young which hatches from the egg and which is known as a nymph, not a larva, resembles the adult, except that at first it possesses no wings and these later appear on the back and grow as the nymph grows.

These characters, taken together, distinguish insects of the Order Orthoptera from those of other Orders.

The insect is a member of the family Blattidæ because:

1. It is cursorial, i.e. it is a running, not a hopping, insect.

2. Its coxæ (basal leg segments) are large and tend to cover the lower side of the body which is flattened dorso-ventrally.

3. The female has an inconspicuous ovipositor.

These characters, taken together, distinguish insects of the family Blattidæ from those of other families in the Order Orthoptera.

Note that the whole insect is enclosed in a more or less hard horny material

"chitin," divided into a number of plates or "sclerites," the breaking up of the armour into sections allowing for bending and general movement.

(1) A rapid survey of the external characters

Dorsal view. Examine the specimen from above and note the small head, bent downwards and almost concealed by the large triangular "tergum" or dorsal plate of the "prothorax," the first of the three thoracic segments. From behind the prothorax there project backwards a pair of wings, each about half the width of the body and somewhat stiffened. Raise these and note, beneath them, a second pair of wings, membranous and with the posterior

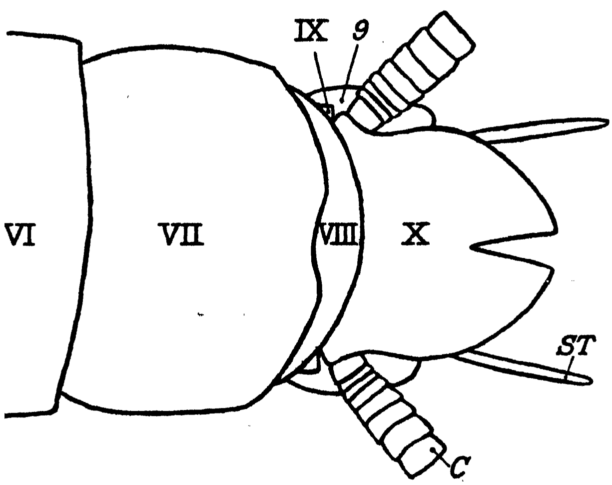

FIG. 1.—Cockroach ♂. Posterior abdominal segments. Dorsal view. Roman numerals denoting terga, Arabic denoting sterna.

C = basal part of cercus; ST = style.

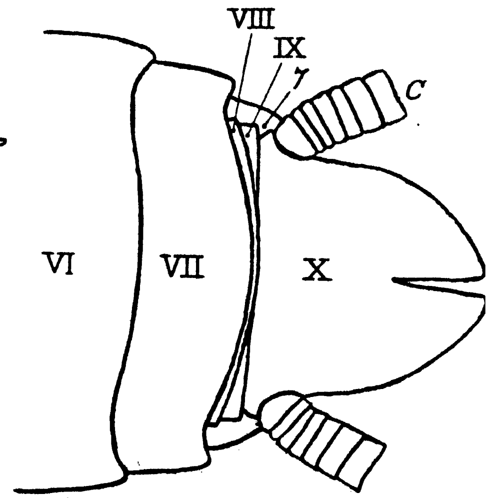

FIG. 2.—Cockroach ♀. Posterior abdominal segments. Dorsal view. The segments are numbered, Roman numerals denoting terga, Arabic denoting sterna.

C = base of cercus.

part folded fanwise. Spread the four wings laterally and note that, by so doing, you can see that each pair is attached to a separate body-segment, the front pair to the "mesothorax" and the hind pair to the "metathorax."

Behind the metathorax note the terga of the "abdomen," which is composed of ten visible segments, of which the 8th is narrow and the 9th is more or less concealed beneath it. The 10th is bilobed posteriorly, and at its edge on each side can be seen a segmented appendage, the "cercus," a sensory process equivalent to the antennæ or "feelers" on the head. Beneath the cerci can be seen the so-called "podical plates," which, if the interpretation be correct, are all that is left of the 11th segment in these insects, a segment which has entirely disappeared in many insects.

Ventral view. A view of the underside of the insect shows (1) the dorsal side of the head which is definitely bent beneath the body when at rest; (2) the underside of the three thoracic segments and of the legs.

Remove completely the three legs on one side of the body, using a fine scalpel to cut the muscles at the base of the legs. This exposes (1) the "coxal cavities" (the holes from which the legs have been removed), (2) the "pleura" or side-pieces of the thorax, and (3) the *sterna* or median pieces. The visible number of the abdominal sterna will differ according to whether you have a male or a female specimen.

In the male all nine sterna are visible, the last bearing a minute pair of "styles"; in the female, there are only seven visible sterna, the 8th and 9th being telescoped within the 7th and forming the "genital pouch" which only becomes obvious when the female is carrying an egg-cocoon or immediately after she has released it (see Figs. 3, 4, 5 and 6). In both sexes the first abdominal sternum is very small.

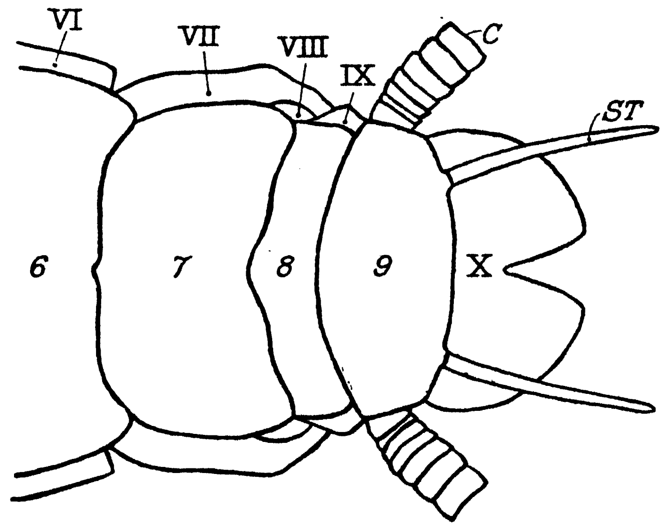

FIG. 3.—Cockroach ♂. Ventral view of posterior end of abdomen. Roman numerals indicate terga, Arabic indicate sterna. C = basal part of cercus; ST = style.

Spiracles. The insect breathes by means of air-tubes or "tracheæ" running throughout the body and branching freely. These tubes communicate with the exterior by openings called "spiracles," of which there are ten pairs—two on the thorax and eight on the abdomen. To find these, look in the membrane between the pro- and meso-thorax and between the meso- and meta-thorax (move the legs forward for this purpose), and, for the abdominal ones, in the pleural membrane between the tergum and sternum of the first eight segments. Stretch the abdomen slightly and look just beneath the anterior angles of each tergum.

(2) A more detailed survey of the external characters

The Head. Examine the head and its attachment to the body and note that, on the neck, there are a number of small brown pieces, "the cervical sclerites," the remnants of what was once a complete segment. The "antennæ," long thread-like structures composed of a large number of seg-

ments. *N.B.*—These are sometimes called joints, but this is not correct as joints are actually the connections between the segments.[1] Note that the basal segment is stouter and of different appearance from the rest of the antenna. In all insects the basal part or "scape," composed of not more than three segments, differs from the apical part or "flagellum." The latter bears sensory

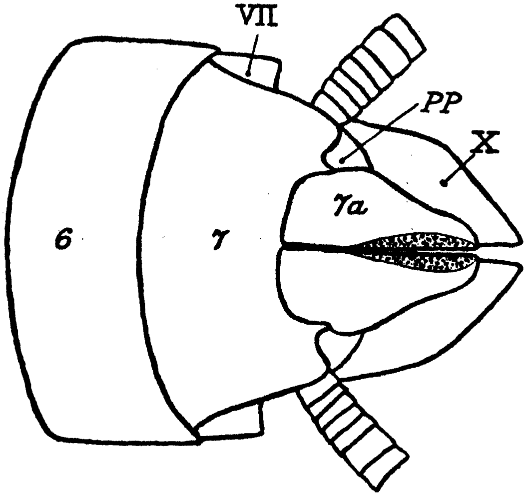

FIG. 4.—Cockroach ♀. Ventral view of posterior end of abdomen. Roman numerals indicate terga, Arabic indicate sterna.

PP = podical plate.

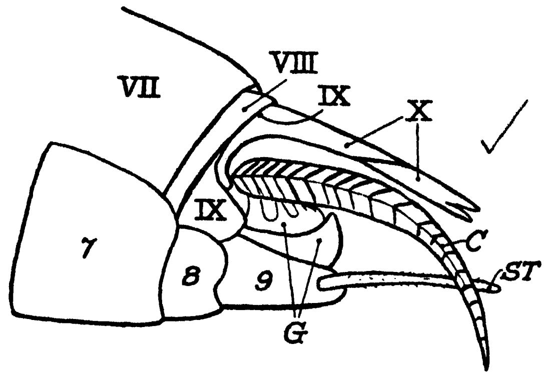

FIG. 5.—Cockroach ♂. Lateral view of posterior abdominal segments, etc. Roman numerals indicate terga, Arabic indicate sterna.

C = cercus; *G* = part of the genital armature (gonopophyses); *ST* = style.

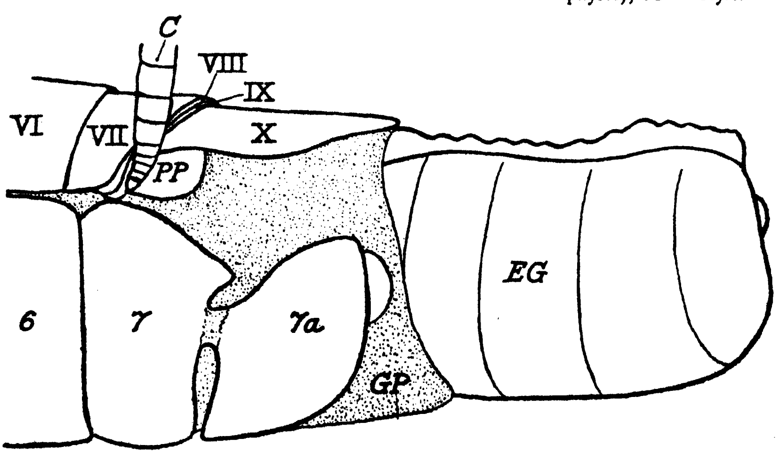

FIG. 6.—Cockroach ♀. The egg-cocoon being carried about. Roman numerals indicate terga, Arabic indicate sterna.

C = base of cercus; *EG* = Egg cocoon; *GP* = the everted genital pouch; *PP* = Podical plate. Dotted areas are membranous.

[1] To those who would regard this as a point too trivial to remark upon, I would point out that entomological nomenclature has been largely created by amateurs and is still in a "sloppy" condition, a condition which can only be got rid of by insisting upon those learning the subject using the correct terms.

structures of which the larger and stiffer hairs may be the external part. Note that each antenna is situated in an "antennary pit" and is connected with the head by one fine strut of chitin, the "antennary sclerite," and loose membrane, to permit of free movement. Note, outside each antenna, a large "compound eye" composed of a number of facets. Many insects have, between these compound eyes and above the antennæ, two or three simple eyes or "ocelli," but these are absent in the cockroach, though present in some other Orthoptera, e.g. the grasshopper. Between and just above the bases of the antennæ note two roundish spots, the "fenestræ," the points at which inpushings have developed during embryology to contribute towards the formation of the internal head-skeleton or "tentorium." (For a description of this structure see Dytiscus, p. 51.) That part of the head above the fenestræ is the "epicranium" and that just below is the "frons," this latter sclerite extending into the "clypeus," the upper part of which is dark in colour and the lower part light. In the American cockroach there is no suture separating the epicranium from the frons, nor are the right and left epicranial plates separated. Similarly there is no suture between the frons and the clypeus. In the common British species, *Blatta orientalis*, the epicranial sutures are distinct, and there is a faint sinuous depression between the frons and the clypeus. Below the clypeus is the "labrum" [1] or upper lip. On each side of the clypeus and labrum can be seen part of the mandible, above which is a more or less triangular plate, mostly dark-coloured but with a paler strip next the mandible,

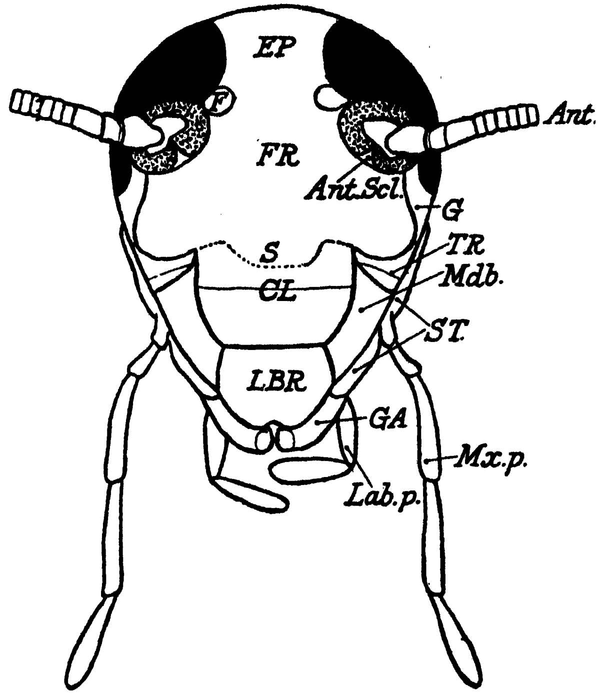

FIG. 7.—Cockroach. The "face."

Ant. = base of antenna; *Ant.Scl.* = Antennary sclerite; *CL.* = clypeus (dark brown above transverse line, pale yellowish below); *EP* = Epicranium—in *B. orientalis* this area is divided into two by a longitudinal median suture and is separated from the frons by a suture, these sutures being absent in *B. americana*; *F* = fenestra; *FR* = frons; *G* = gena; *GA* = galea of maxilla; *LBR* = labrum; *Lab.p.* = labial palp; *Mdb.* = mandible; *Mx.p.* = Maxillary palp; *TR* = trochantin of mandible; *ST.* = stipes; *S* = fronto-clypeal suture, absent in *B. americana* but present in *B. orientalis.*

[1] It is useful, when making notes, to use certain abbreviations for the mouth-parts: Lbr. for labrum; Lab. for labium; Mdb. for mandibles; Max. or Mx. for maxilla; and Mx.p. and Lab.p. referring to their respective palps.

which is the "trochantin of the mandible." Outside the mandible is a 4-segmented feeler, the "maxillary palpus." Part of the maxilla is visible on each side below the labrum and also another pair of short 3-segmented palps, the labial palpi.

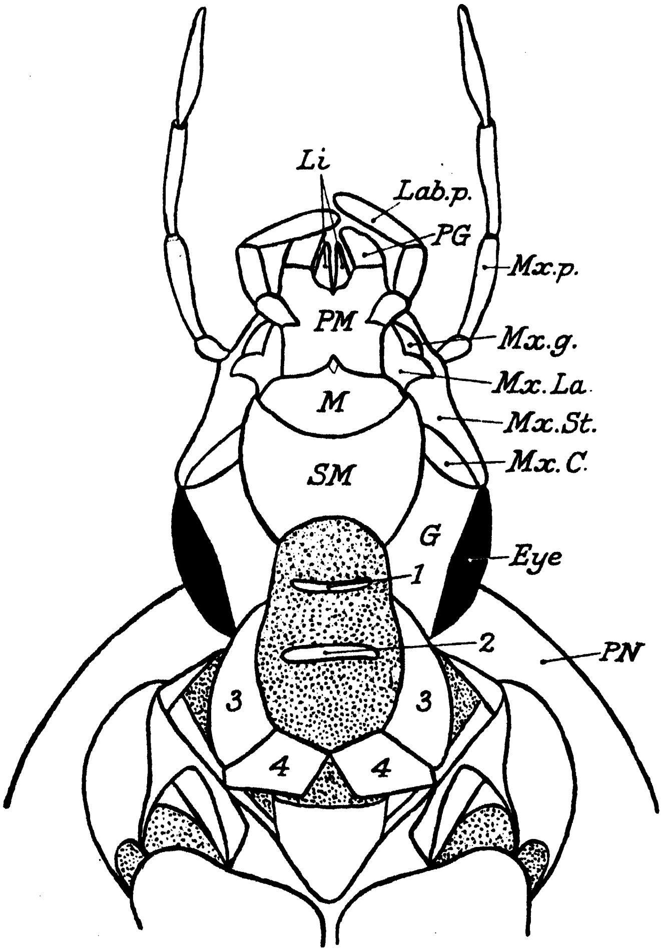

FIG. 8.—Cockroach. Ventral view of head, "neck" and first thoracic segments.

G = gena; *Lab.p* = labial palp; *Li* = ligula (laciniæ of labium); *M* = mentum; *Mx.p* = maxillary palp; *Mx.C* = cardo; *Mx.g* = galea; *Mx.La* = Lacinia; *Mx.St* = stipes of maxilla; *PG* = paraglossa (galea of lab.); *PM* = pre-mentum (sub-galea); *PN* = pro-notum; 1, 2, 3 and 4 = cervical sclerites; *SM* = sub-mentum.

Now remove the head and examine it ventrally. Note the "occipital foramen," the hole in the head-capsule left by cutting through the neck. In front of this is a large plate, the "sub-mentum." Anterior to this is the "mentum," on which is a piece (in some insects called the "sub-galea" [1]) bearing on each side a labial palp, and, anteriorly between the palps, are two large outer and two small inner pieces. The "labium" consists of a pair of appendages which have become fused together. Each appendage consists of a basal piece or "cardo," a middle piece or "stipes" bearing a palpus, and, at its apex, an inner piece, the "lacinia" or blade, and an outer piece, the "galea" or hood; but note that, in the case of the labium, the two galeæ are called "paraglossæ" while the laciniæ form the "ligula."

Hold down the head and gently bend back the labium and you will see a spathulate structure attached to its inner face. This is the true tongue or 'hypopharynx." Note

[1] The term "sub-galea" is useful as it is without definite morphological meaning. Sometimes it is part of the stipes in the maxilla or mentum in the labium (in the latter case called the "prementum"), and sometimes it is the lower part of the galea marked off from the upper part by a suture.

on each side of the labium, when lying at rest, an elbow-like projection; this is the basal part of the "maxilla."

Now carefully remove the labium without disturbing the maxillæ. The tongue will probably remain attached to the head, but, on each side, the maxillæ will be completely exposed.

Note that, like the two halves of the labium, each maxilla consists of cardo, stipes, palp, galea and lacinia, the only difference being in this case there is a small piece cut off from the stipes and supporting the palp and known as the palpiger (or palpifer).

Now remove the maxillæ and tongue and draw a complete maxilla. Notice, after removing the maxillæ, that two "genæ" or cheeks have become visible, one on each side of the head, and that the mandibles are now exposed. Move them and note that they articulate with the genæ and the juncture of the frons and clypeus, by means of a hinge, while maxillæ and labium are only attached to the head by membranes. Draw a mandible. Make a permanent mount of the maxillæ and labium, leaving out the mandibles because of their bulk.

The Thorax. Note the straight-veined wings and the tendency in the fore-wings to become thickened and protective structures.

Examine the attachment of the fore-wing to the body, and note at the base, posteriorly, a little lobe, the "jugum" or "jugal lobe."

Remove part of the tergum of the prothorax and note, at the extreme base of the wing on the anterior margin, a small pale-coloured plate, the "tegula," which, in some insects, is greatly developed.

The wings are attached to the thorax by the "axillary membrane," and, in this, are embedded a few small plates, the "axillary sclerites." The posterior margin of the hind-wings runs into the body on a thickened chord, the "axillary chord."

Make a diagram of the wing to show jugum, tegula, etc.

Ventral view of the Thorax. Owing to the flattened form of the insect, a ventral view shows, not only the sterna of the segments, but also part of the pleura (see Fig. 9 and also a lateral view in Fig. 10). These latter, however, are considerably reduced, owing to the very large size of the leg-bases, which occupy most of the space. The pleura of the earwig are more easily recognized (see Fig. 11).

The pleuron of a thoracic segment of any insect consists of two main sclerites, an anterior "episternum" and a posterior "epimeron," the former being frequently divided into two, the anterior being the "pre-episternum." The two main sclerites are separated by the "pleural suture," which is the first thing to determine. In the meso- and meta-thorax it runs from the point where the coxa connects with the pleuron to the "pleural-wing-process," the point at which the anterior part of the wing is attached to the thorax. In the

prothorax this suture is usually easy to determine, in spite of the absence of a wing.

In the cockroach, the pre-episternum is present only in the prothorax (in

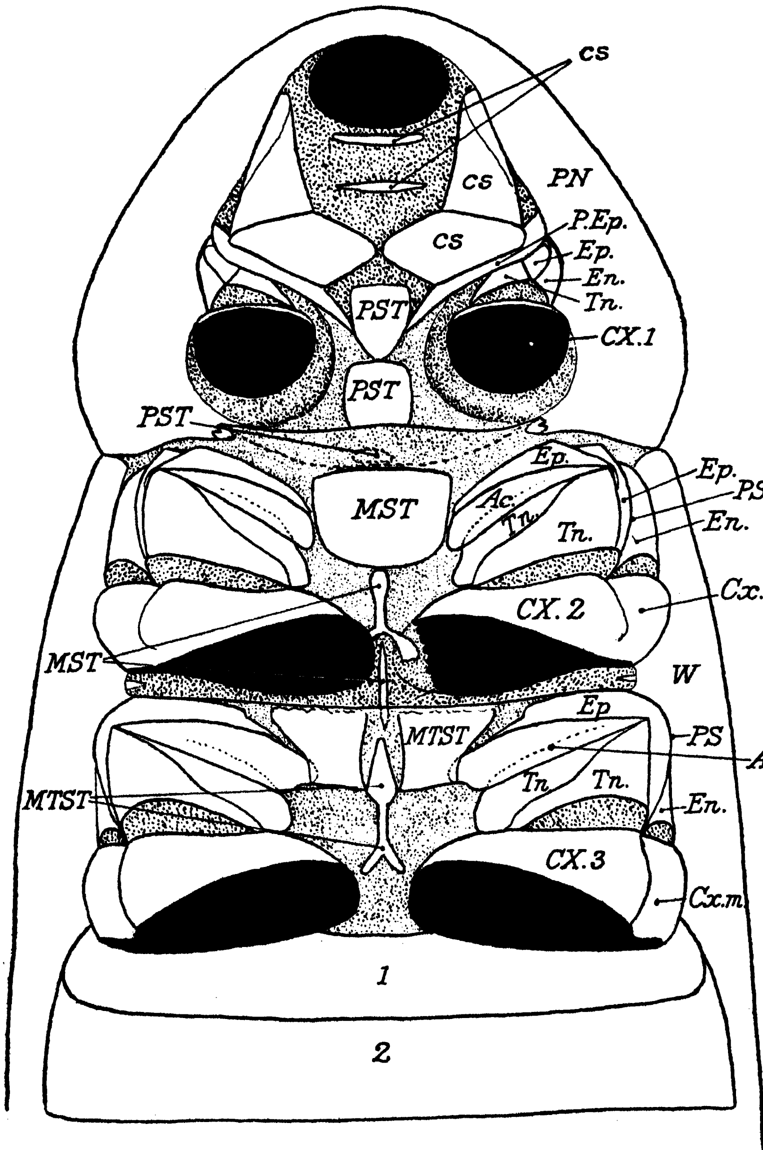

FIG. 9.—Cockroach. Ventral view showing thorax and anterior abdominal segments. The head is removed, leaving the "neck" showing cervical sclerites (*C.S.*).

Ac = Ante-coxal plate; *Cx.* 1, 2 and 3 = the coxæ cut off; *Cx.m.* = coxa meron; *Em* = epimeron; *Ep* = episternum; *P.Ep* = pre-episternum; *PN* = underside of pro-notum; *PS* = pleural suture; *PST*, *MST*, *MTST* = pro-meso and meta-sternal sternites; *Tn* = trochantin; *W* = the fore-wing. Two abdominal sterna (1 and 2) are shown.

the earwig it occurs in both pro- and meso-thorax), but it is of frequent occurrence in insects, especially in the less-specialized Orders.

The sterna of the thoracic segments are composed of several "sternites,"

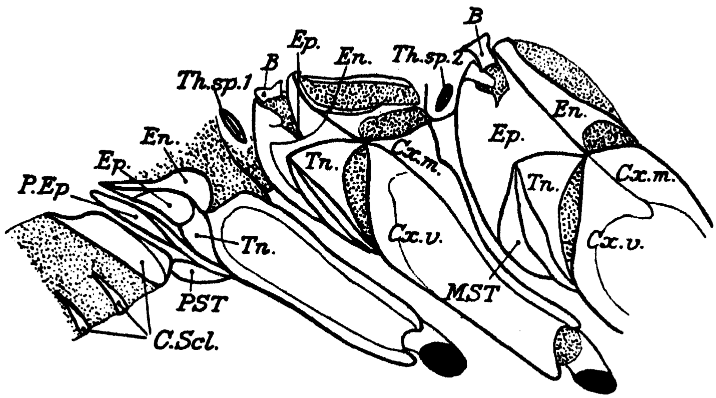

FIG. 10.—Cockroach "Neck" and thoracic pleura.

B = Basilare, one of the epipleurites of the wing-segments; *C.Scl* = cervical sclerites; *Cx.v.* = coxa vera; *Cx.m* = coxa meron; *En* = epimeron; *Ep* = episternum; *MST* = meta-sternum; *P.Ep* = pre-episternum; *PST* = pro-sternum; *Tn* = trochantin; *Th.Sp.* 1 and 2 = 1st and 2nd thoracic spiracles.

which may number four or five but, in the majority of insects, are reduced to two. In the cockroach three are recognizable in the pro- and meso-segments. Frequently, between the episternum and the coxa, there is a sclerite, sometimes

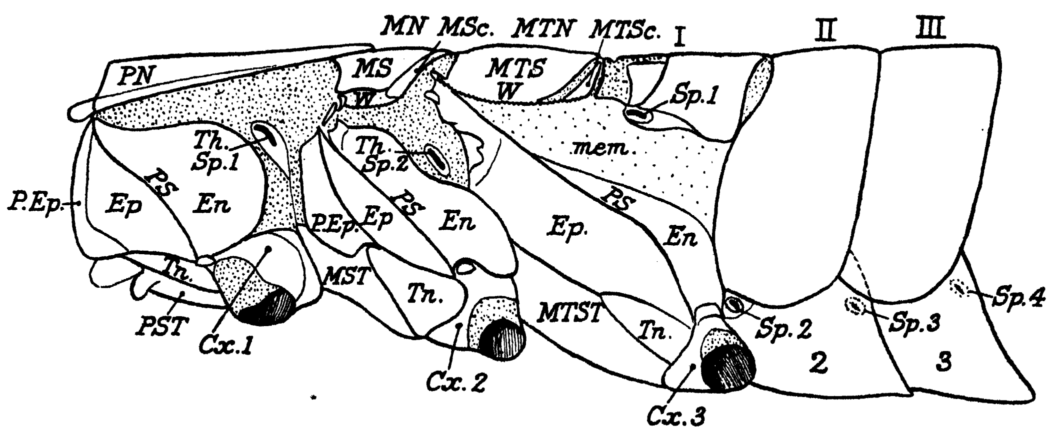

FIG. 11.—Earwig ♀. Lateral view of thorax and anterior abdominal segments.

Cx. 1, 2, and 3 = the coxæ; *En* = epimeron; *Ep* = episternum; *MS* = meso-scutum; *MSc* = meso-scutellum; *MTS* = meta-scutum; *MTSc* = meta-scutellum; *P.Ep* = pre-episternum; *PS* = Pleural suture; *PN*, *MN*, *MTN* = pro-meso- and meta-notum; *PST*, *MST*, *MTST* = pro-, meso- and meta-sterna; *Th.Sp.* 1 and 2 = 1st and 2nd thoracic spiracles; *Tn* = trochantin; *Sp.* 1, 2, 3, 4 = the first four abdominal spiracles; *W* = line of wing-attachment; I, II, III = terga of 1st, 2nd and 3rd abdominal segments; 2 and 3 = 2nd and 3rd sterna; *mem* = semi-membranous area.

double—as in the cockroach—the "trochantin" (not to be confused with the trochanter, which is a leg-segment), and, sometimes also, there exists, as in the

cockroach, an additional sclerite, the "ante-coxal plate." The true relationship of these sclerites, whether they belong to the pleuron or to the sternum, is not understood.

Examine a leg [1] and note that it is composed of:

1. A large basal coxa, which is composed of a larger anterior piece, the "coxa vera" and a smaller posterior piece, the "coxa meron."
2. A small intermediate segment, the "trochanter."
3. A long "femur."
4. A still longer and hairy "tibia."
5. A "tarsus" consisting of five segments, the basal one long and the apical one longer than the intermediates and bearing, at its apex, two claws, between which is a pad or "empodium." *N.B.*—The number of tarsal segments and their form is often of importance in classifying insects.

Draw the leg.

The Abdomen. This has been described sufficiently for this stage on pp. 4 and 5, and, as the genital armature is highly complex in these insects, a simpler type of male and female is described under Dytiscus.

Dissection

It is preferable to use a freshly-killed specimen for the dissection as the internal structures are much less brittle and things are therefore much more easily seen and moved about. Killing for immediate dissection is effected easily, either by chloroform vapour or by dipping the insect into boiling water for not more than a few seconds. Should a freshly-killed specimen not be available, take one which has been preserved in spirit [2] and soak it for several hours in warm, not hot, water; e.g. by placing upon the lid of the paraffin bath. It is easier to dissect such soaked specimens than those taken straight from the preservative.

Fix the specimen down, dorsal side uppermost, in the dissecting-dish, preferably by first melting some paraffin wax and embedding legs and ventral part of body in this and then pinning this wax on the cork or wax in the bottom of the dish. If loose wax is not available pin the insect into the dish, pushing the pins only through the sides of the prothorax and through the spread wings. If the insect is embedded, cut off the two pairs of wings near their bases. If your specimen is a male, and your insect is embedded so that the abdomen cannot move, place a pin in the wax beside the 5th abdominal segment. This segment is more easily found while the terga are undisturbed, and the testes lie partly

[1] If the leg has been removed from the body, note that, possibly, part of the thorax may remain attached to the coxa.

[2] Specimens for preservation in spirit should first be fixed, either by dropping into boiling water and boiling for five minutes or longer or by dropping into one of the usual fixatives, such as Carnoy, Bouin, etc.

in it and partly in the 4th, and, as they are difficult to find, it is well to know exactly where to look for them. Gently push the point of a pair of fine scissors beneath the posterior edge of the penultimate abdominal tergum near the side of the body, not in the mid-dorsal line, and cut the tergum forwards, being very careful to cut so as to avoid damaging anything beneath. Continue to cut forward to the posterior margin of the thorax and then proceed in the same way up the opposite side. Then, with fine forceps, lift the terga and remove them. If this has been done successfully, the heart will be exposed in the median line, running forward from about the 8th abdominal segment to the anterior end of the abdomen. It consists of eight chambers or "ventricles" connected with one another through inter-ventricular valves which only allow the blood to pass forward.

In each side of each chamber is an opening "ostium" protected by a valve which only allows the blood to pass into the heart from the surrounding pericardial cavity.

Note the "alary muscles," arranged like a series of triangles on each side of the heart. These lie in the pericardial membrane, and, by their contraction, reduce the pericardial cavity and thus exert slight pressure upon the blood and aid its passage into the ostia. Remove part of the heart and pericardial membrane and examine under a microscope.

In removing the heart, etc., the dorsal muscular body wall (which may have been previously removed with the terga) will come away, and beneath and on either side of the heart will be seen a greater or less amount of opaque white substance, the "fat body." This varies in quantity according to the condition of the insect, increasing when there is plenty of food and diminishing with starvation. It is therefore a reserve material.

It is possible that a number of dumb-bell-shaped bodies may be seen free in the "hæmocoel" or "body cavity." These are protozoal parasites ; Gregarines (Diplocystis) (see paper by Dobell and Jameson, *Q.J.M.S.* 1919).

If the insect is a female, part of the "ovaries" may be visible projecting upwards on either side and even meeting in the median line embedded in fat body if oviposition is near, and towards the posterior end, a fine vermiform structure, part of the female "accessory glands"; unless the ovaries are ripe most of the visible space is occupied by the "alimentary canal."

With a fine brush or pipette clear out any diplocystis or other loose material, and, before moving the alimentary canal, note in the anterior of the abdomen the "proventriculus," and possibly part of the "œsophagus," the most anterior part of the gut so far visible. Again at the posterior end, in the region of the 7th abdominal segment and behind a constriction in the gut, note the "rectum."

Having determined these parts of the gut, free the whole intermediate part from its attachments—it is largely held in position by tracheal tubes—and spread it out at one side without damaging or cutting it.

Note (1) The "mesenteron" or mid-gut (sometimes called "stomach" or "chilific ventricle"), a comparatively narrow, more or less white tube, bearing at its anterior end seven or eight mesenteric cæca (sometimes wrongly called "hepatic cæca").

At the posterior end of the mid-gut is a thickening, the "pyloric ring," from which numerous fine tubes, "malpighian tubules," arise. This ring is the boundary line between the mid-gut and the "proctodæum" or hind-gut. This latter consists of a very short "small intestine," a long, usually dark-coloured, "large intestine" and the rectum already mentioned.

Now remove the terga of the three thoracic segments and you will see exposed more fat body and a number of large muscles which control the wings. Remove these carefully so as to expose the anterior part of the gut, the "stomodæum," which extends from the mouth to the commencement of the mid-gut.

Immediately in front of the proventriculus is a large sac-like "œsophagus," tapering forwards into the "pharynx" in the head. In the prothorax, on either side of the œsophagus, lie the "salivary glands," each consisting of two masses of opaque white bodies with a "salivary sac" between them.

The ducts from these two glands can be traced descending beneath them and passing forwards to unite beneath the œsophagus to form a "common salivary duct," which opens into the floor of the mouth. Cut out the œsophagus and mid-gut in one piece and slit up. Note that the proventricular lining projects into the mid-gut forming the "proventricular" or "œsophageal valve."

In the proventriculus, note the chitinous teeth in six series and the groups of setæ, all projecting back towards the mid-gut. The proventriculus, the posterior part of the stomodæum, although sometimes called the "gizzard," is not a grinding apparatus so much as a filter. It allows solids to pass on into the mid-gut but not in the reverse direction, whereas fluids can easily pass either way.

If time permits, stain the proventriculus, e.g. with borax carmine (taking care not to overstain), and make a permanent balsam mount. Having removed the alimentary canal, the "nervous system" and the "reproductive system" are exposed, but, before passing on to them, a few other things may be attended to. The "tracheal" or "respiratory system" is spread throughout the insect, and a piece of one of the large lateral tracheal trunks, removed and mounted, will give an idea of the structure of any of the larger trachea. It will be seen that a spiral thickening lines the wall of the tube, thus preventing the lumen from becoming completely obliterated when the tube is kinked or compressed, and an examination with a high-power microscope will reveal the fact that the walls are composed of nucleated cells, of which the chitinous lining and spiral thickening are the secretion.

Staining with carmine will probably make clearer the nuclei and the cellular structure. An examination of muscle, teased out upon a slide, will show that,

from whatever part of the body it is taken, it is all striped, whether "voluntary" or "involuntary" muscle. The central nervous system, lying in the mid-ventral line, consists of a number of paired ganglia united by longitudinal commissures. Thus the ventral chord is double and consists of six pairs of abdominal and three pairs of thoracic ganglia. [Do not try to see the 6th pair of ganglia until you are examining the reproductive system later on.] In front of these is a "sub-œsophageal" pair in the head, from which two lateral commissures pass up, one on each side of the œsophagus, to the "supraœsophageal ganglia" or "brain." Each ganglionic mass gives off lateral nerves, and, although the whole system is linked up and presumably controlled by the brain, there is "local government" in the segments themselves. In addition to this main double nervous system, an unpaired sympathetic system lies along the median dorsal line of the œsophagus and is connected with the main double system anteriorly.

Beneath the brain is a small "frontal ganglion" from which nerves go out, one on each side, to connect with the lateral commissures and branches from these nerves go forward to the labrum.

From the frontal ganglion, the "recurrent nerve" runs backwards, giving off branches laterally to a small pair of ganglia well forward, each small ganglion being connected with a small mass, said to be glandular, the two masses being called "corpora allata."

On the posterior region of the œsophagus the recurrent nerve expands into a "triangular ganglion" which gives off nerves right and left. This system is said to control the heart and the anterior spiracles and tracheæ.

A ventral sympathetic system is associated with the ventral chord, a median nerve arising out of each ganglionic mass and branching to right and left, these branches passing to the spiracles and controlling the closing apparatus behind them. (The description of the sympathetic system is only included in case some part of it should attract the attention of the student. The system is dealt with in detail under Dytiscus.)

The Reproductive System

Male. The "testes" which are embedded in fat body at the sides of the 4th and 5th abdominal segments somewhat resemble a bunch of grapes, and consist of a number of colourless clear globules embedded in opaque white.

They are not easy to find at any time, but, as the male is only functional during a limited period of its life, these glands apparently disappear after that period is over.

From each testis a fine tube, the "vas deferens," passes downward on each side to the so-called "mushroom-shaped-body" which lies in the mid-ventral line.

This body is the fused "vesiculæ seminales," one for each vas deferens, and these two storage sacs open posteriorly into the "ejaculatory duct." This runs back to open to the exterior behind the 9th sternum, i.e., below the anus, which opens behind the 10th sternum, the 11th sternum being absent.

Surrounding the genital aperture are several chitinous structures which constitute the "genital armature" and are called "gonapophyses."

Female. Assuming that the female is not ripe, the removal of the alimentary canal has exposed the ovaries and a large mass of fine tubes occupying the posterior end of the abdomen. These are the "accessory glands," or so-called "colleterial glands," whose secretion contributes to the formation of the egg-capsule.

Remove this mass very carefully, piece by piece, taking care not to damage some rather opaque white bodies lying beneath, the "oviducts" which are formed on each side by the union of the "ovarioles" or egg-tubes. Eight of these tubes compose each ovary and each tube contributes one egg to a batch of sixteen laid in each egg-capsule.

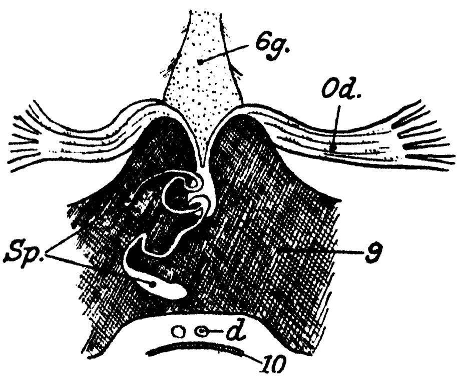

FIG. 12.—Cockroach. View of 9th sternum from above (inside the body). Diagram showing the spermathecal duct passing through the notch in the anterior border of the 9th sternum, into the dorsal wall of the "common oviduct."

d = duct of accessory (colleterial) gland;
6g. = 6th abdominal ganglia;
Od. = oviduct; *Sp.* = spermatheca and spermathecal gland;
9 and 10 = parts of the 9th and 10th sterna.

Having cleared away a large part of these accessory glands, it may now be possible to insert a fine pin on each side behind the ovaries through the sternum of, say, the 7th segment into the wax, so as to spread out the exposed parts.

The removal of the glands will expose the 6th pair of ganglia of the central nervous system and a little behind this ganglionic mass is a short thick tube bent upon itself, part of the spermatheca, in which the spermatozoa, received from the male, are stored.

Note that the two oviducts turn forward and pass down, one on each side of the 6th abdominal ganglia, disappearing beneath a pair of brown chitinous lobes, which project slightly upwards. These are the anterior part of the sternum of the 9th segment. Beneath this, the oviducts unite into the "common oviduct" and pass to the "vulva," situated in a partially chitinized area between sterna seven and eight. Immediately behind the point of junction of the two oviducts, the "spermathecal duct" enters the common oviduct immediately inside the vulva.

N.B.—It is usually stated that the spermathecal duct opens "on the 9th sternum."

This is not correct. The 9th sternum is deeply notched anteriorly in the median line and through this notch the spermathecal duct passes (see Fig. 12).

The accessory-gland-ducts open into the genital pouch between the larger gonapophyses.

The female genital opening within the genital pouch is surrounded by three pairs of minute chitinous structures, the gonapophyses, which together form the "sexual armature."

II. EXTERNAL CHARACTERS OF INSECTS

(1) *Primitive type. An example of the A-pterygota: Order Thysanura* (Lepisma ("Silverfish") or Machilis).

This is one of the simplest insects as is shown by (1) the general similarity between thoracic and abdominal segments, (2) the absence of wings, (3) the very slight reduction of the abdomen, all the segments being more or less alike.

Draw a dorsal view of the whole insect. Remove head and boil in potash. Examine the mouth-parts (Mandibles, Maxillæ, and Labium) and mount the head whole to show these.

They are of the "mandibular" type (Lepisma is not so simple as Machilis).

Note that the young stages of A-pterygota differ but little in appearance from the adult, another indication of the primitive condition of these insects.

(2) *An example of the Exopterygota: Order Rhynchota* (*Hemiptera*), "Bugs" (Notonecta, "Water Boatmen," or Nepa, "Water Scorpion").

Note the upper pair of wings, partly stiffened and covering the hind-wings and hind-body. Note the large posterior pair of legs fringed with hairs and specialized for swimming, in Notonecta more than in Nepa.

This bug lives and feeds in the water, but can leave it and fly from one place to another. Both pairs of wings are organs of flight, as in cockroaches, grasshoppers, etc.

Remove the head and boil in potash and examine the mouth-parts. Note the labium (rostrum), a segmented structure with a groove in its upper surface, the base of the groove being covered by the short labrum. In the groove of the labium are two pairs of stylets, one of which is the metamorphosed mandibles and the other, of which the two structures are hard to separate, is the metamorphosed maxillæ. Draw the mouth-parts.

(2*a*) *The nymph of Notonecta or of Nepa.*

Note the compound eyes and externally-developing wings and the general similarity in appearance to the adult, both young and full-grown individuals living under similar conditions. Both stages require to come to the surface to renew their air supply, so that some of the spiracles are open. Find these in the nymph.

(3) *An example of the Exopterygota: Order Odonata*, "Dragonflies" (Agrion or other Zygopterid).

Make a drawing of the insect and note the wings with net-veined venation,

a sign of primitiveness amongst winged insects. Examine the mouth-parts *in situ* and note that they are of the "mandibulate" type.

(3*a*) *The nymph of the "dragonfly"* (Agrion or other Zygopterid). Lives in water and takes two or three years to mature. It breathes through the skin and also through the three lamellæ at the apex of the abdomen, but it can still live if these latter are removed, although they may grow again. All the spiracles are closed and the nymph does not come to the surface to renew its air supply and is, therefore, well adapted for an aquatic life. It becomes "propneustic" in the last stage before emergence as an imago, i.e. one pair of thoracic spiracles becomes functional, and it is then quite usual to see nymphs without the lamellæ.

Note the external wing-pads on the 2nd and 3rd thoracic segments. Examine the mouth-parts and note the elaboration of the labium, which is capable of projection forwards and of withdrawal beneath the mouth. The labial palpi are modified into jaw-like structures for seizing the prey, which consists of living insects, etc. The modified labium is called the "mask" and the mouth-parts are "mandibulate." Mount the mouth-parts.

Note that the growing stages of the Exopterygota are known as "nymphs" as distinct from "larvæ" which are the growing stages of the highest group of insects, the Endopterygota. The main external characteristics of nymphs are: (1) Compound eyes as against simple eyes in larvæ; (2) externally-developing wings, as against wings developing in pockets in larvæ; (3) external sexual armatures, which do not develop in larvæ.

(4) *An example of the Endopterygota: Order Coleoptera*, "Beetles" (Cockchafer or other Scarabæid).

Examine the insect carefully, noting (1) the form of the antennæ, which vary greatly in different groups of beetles, the form being of systematic importance, (2) the nature of the mesothoracic (anterior) wings, stiffened to form a covering for the hind-body and no longer of any use as organs of flight and called "elytra." Remove the elytra and note (3) the metathoracic (posterior) wings which fold in a characteristic manner beneath them and are the organs of flight.

Detach the head and boil it in potash ; remove the mouth-parts, make a permanent mount of them and draw them.

(5) *Another example of the Endopterygota: Order Lepidoptera*, "Butterflies and Moths."

Butterfly (Large White or Common Tortoiseshell, etc.).

Note the two pairs of large wings covered with minute scales (modified hairs). Spread the wings in order to see that the front edge of the hind-wing is enlarged at its base so as to underlie the fore-wing when in flight. Moths and many other insects have a more or less elaborate wing-coupling apparatus to ensure the wings working together in flight, but in butterflies there is only this overlap.

Scrape some scales from a wing; mount them and draw. Note the knobbed antennæ (a character which, by itself, will almost always distinguish a butterfly from a moth, whose antennæ are rarely knobbed), and the coiled proboscis (the two maxillæ) which lies beneath the head. There are no mandibles.

Remove the head and boil in potash. Take off the eyes, the top and sides of the head and mount the mouth-parts so as to show the two maxillæ, each with its small palp, and the small labium with a pair of three-segmented palps. In a few primitive Lepidoptera the mouth-parts are much simpler and are of the "mandibulate" type.

(5*a*) *The larva of a butterfly or moth* known as a "caterpillar" (Large White or of a Noctuid Moth or a Silkworm).

Note the three pairs of thoracic legs and a number of abdominal "prolegs." There are never prolegs on the first abdominal segment and seldom on the second in the larvæ of Lepidoptera. Note the one pair of thoracic and eight pairs of abdominal spiracles.

Examine the head and note the six simple eyes on each side. Note the simple mandibulate mouth-parts, the simple labium with a large "spinneret" (hypopharynx or tongue), at the apex of which is the opening of the salivary duct. The silk, which is the saliva, issues from the duct.

(5*b*) *The pupa of a butterfly or moth*, in some cases called the "chrysalis" (Pupa of Large White or Tortoiseshell or Silkworm Moth).

Note that in the change from larva to pupa, the wings have appeared. The pupa shows most of the parts of the adult, but they are all glued down to the body and this type of pupa is the "pupa obtecta." Draw.

(6) *Another example of the Endopterygota: Order Hymenoptera*, "Ants, Bees, Wasps, etc." (Vespa (wasp) *and* Bombus (Humble-bee) or Apis (Hive-bee)). Two types of Hymenoptera showing similarity in wings but with mouth-parts remarkably different. Examine the wings of both insects and note the general similarity in form but slight differences in the arrangement of the veins. Note also the gauzy nature of the wings.

Mount the fore- and hind-wings of one side of either insect and note the wing-coupling apparatus, a series of small hooks on the anterior margin of the hind-wing which engage with the downturned posterior margin of the fore-wing and thus ensure the two wings working together. Draw.

Remove the mouth-parts of both insects after boiling the heads in potash; mount and compare. Note the labium (ligula, paraglossæ and palpi); maxillæ (with cardo, stipes, lacinia, galea and palp); and mandibles. The mouth-parts of the wasp are "mandibulate," those of the Bee are "haustellate." Draw.

Although these types of mouth-parts are so different, the latter has evolved from the former, and amongst the bees various stages in this evolution can be seen. The following show degrees in the evolution of the maxilla: Cephid Sawfly, Tenthredinid Sawfly, Vespa, Andrena, Melecta, Apis (or Bombus).

The following show stages in the evolution of the Labium: Prosopis, Colletes, Sphecodes, Cilissa, Nomada, Apis (or Bombus).

(6*a*) *The larva of a bee or wasp*, sometimes called "grub."

Note the small pale-coloured head with "mandibulate" mouth-parts and the absence of distinction between thoracic and abdominal segments, the larva being legless. Legless larvæ, with few exceptions, are only found either in insects in which the egg is laid in the midst of food material or in insects which feed their young during the larval period.

(6*b*) *The pupa of a bee or wasp.*

Note the similarities and differences between this pupa and that of the Lepidoptera. This type is called a "pupa libera" because the antennæ, mouth-parts and legs are not glued down to the body. Draw.

(7) *Another example of the Endopterygota: Order Diptera*, "Flies" (Two types: Culex (Gnat) and Calliphora (Blowfly) or Musca, (House-fly)).

Note that in both types there is only one pair of wings, the hind pair being represented by small projections, the "halteres" or balancers. This is the chief characteristic of the Order.

CULEX (Type of biting fly). Examine the wings and note that the membrane is clear, that the veins are covered with scales (modified hairs) and the wings fringed with them. The antennæ of the female, although fringed with hairs, are much less ornate than those of the male; the maxillary palpi are short, instead of long as in the male, and the mouth-parts consist of labrum, labium and stylets, whereas stylets are absent in the male. Only the females suck blood.

Remove the head, boil in potash and mount whole, teasing out the stylets from the labial groove without breaking them so that, in the mounted specimen, all the parts are visible, viz., labrum, labium, two maxillary stylets and palpi, two mandibular stylets and hypopharynx, with salivary duct running through its whole length. Note the small "labella" (at the apex of the labium, representing all that remains of the labial palpi, which are absent in the Diptera. Draw.

CALLIPHORA (Type of non-biting fly). Compare the wings of this type with those of the gnat and note that the arrangement of the veins is different, venation being an important character in the division of the order into families.

Examine the mouth-parts and note the large labella at the apex of the labium. Remove the head, boil in potash and mount, after separating the labrum and the hypopharynx and placing the labium flat so that the labella are expanded side by side.

Note the absence of mandibular stylets and note also, on the under side of the labella, the "pseudotracheæ," the filtering apparatus which strains the fluids sucked up by the fly. Draw.

The evolution of the mouth-parts of the Diptera has been in the reduction in number of the parts and the enlargement of the labella. The more primitive flies have all the usual parts (e.g. Culex, Tabanus, etc.). The mandibles are

the first parts to disappear, e.g. Eristalis, etc. Then the maxillæ also disappear, e.g. Calliphora, Musca, etc.

In the majority of flies the tongue (hypopharynx) is well developed; better than in other orders.

(7*a*) *The larvæ of Diptera* are of two main types, those with distinct heads and those without them. As examples, examine the larvæ of the gnat and the blowfly.

Type 1. Gnat. The larva and pupa are aquatic but come to the surface at intervals to renew the air supply.

Larva. Note on the back of the 8th abdominal segment a projection, the siphon, at the end of which there is a pair of spiracles. These are the only functional spiracles, and, in renewing the air supply, the larva brings the tip of the siphon to the surface and hangs suspended. Note the mouth apparatus fringed with hairs. The vibration of the feathered antennæ sets up currents of water around the mouth and small organisms are caught in the feathered mouth-parts.

Because of the position of the spiracles, near the posterior end of the body, the larva can breathe and feed at the same time. It is heavier than water and only reaches the surface by swimming. Note the absence of legs. No fly larva has legs. Draw a side view of larva.

(7*b*) *Pupa.*

Note the enlarged thorax and small abdomen bent underneath, with a pair of "paddles" at the posterior end. On the prothorax is a pair of respiratory trumpets, with a spiracle at the apex of each. These are the only functional spiracles on the pupa.

Thus the pupa breathes head end up, the opposite way to the larva, and whereas the larva is heavier than the water, the pupa is lighter and can only get away from the surface by swimming. The change is important, because the imago has to escape into the air by breaking through the thoracic skin of the pupa and therefore this region is maintained in contact with the surface film. Draw a side view of pupa.

Type 2. Blowfly. Unlike the gnat larva, it has two pairs of open spiracles, but the more important pair is at the posterior end of the body. A small pair will be found on the sides of the 1st segment.

This larva is immersed in the semi-fluid food and keeps its posterior spiracles exposed to the air. Note the absence of head and the mouth-parts projecting from the prothorax. Draw the larva, showing mouth-hooks and spiracles.

The headless fly larvæ, and some of those with heads, change to pupæ inside the larval skin, which stiffens and forms a brown case or "puparium" enclosing the pupa. In the puparium, the larval tissue breaks down and is rebuilt into the pupa. Draw a puparium, noting the remains of body segmentation, larval spiracles, etc.

III. THE ORDERS OF INSECTS

You have already seen something of the characters upon which some of the more important Orders of insects are distinguished, specimens belonging to six or seven of these Orders having been shown you. You are likely to come across, in the ordinary everyday life, specimens of a number of other Orders such as some of the following:

1. **Isoptera** (Termites or so-called "White Ants") have, like the real ants, winged male and female and wingless workers. The wings show the more primitive net-venation which has disappeared in the higher Orders.

The Termites are remarkable for polymorphism, a community consisting of a King, a Queen, "soldiers" with large mandibles (they are often scavengers rather than fighters) and workers.

(Examples of these "castes" should be shown.)

2. **Anoplura** (Biting and Sucking Lice).

(*a*) *Mallophaga* (Biting or Bird-Lice), so called because, although some are found on Mammals (e.g. cats, dogs, horses and cattle), the majority are found upon birds, feeding mostly upon epidermal products, such as dead cuticular substances.

Note the strong mandibles.

In accordance with habits, the eyes are reduced and the wings have disappeared, although the group is descended from winged ancestors.

(*b*) *Siphunculata* (Sucking Lice). Blood-sucking parasites on mammals, including man. Similar adaptations to habits seen in Mallophaga but with mouth-parts modified for sucking.

3. **Thysanoptera** (Fringe-wings or Thrips). A group of minute insects with sucking mouth-parts. They suck the sap of plants and sometimes are very abundant, and do much damage. When one suffers from a "fly in the eye," it is frequently a Thrips which is the real culprit.

4. **Ephemeroptera** (May Flies). An Order of aquatic insects, the definition of an aquatic insect being an insect which spends some part of its life in the water. (Very few insects spend the whole life-cycle in the water.)

The nymphs possess tracheal gills and do not require to come to the surface to renew their air supply.

A peculiarity of this Order is that the nymph emerges as a winged form "sub-imago" which, after a short period, casts its skin and appears as the imago.

In the adults, note the net-venation of the wings, an indication that the Order is one of the more primitive ones.

B. Endopterygota

5. **Neuroptera** (Ant-lions, Alder flies, Lacewings, etc.). At one time the Neuroptera included all the insects with net-veined wings, as the name implies; that is, Bird-lice, Termites and their relations, Dragonflies, Stone flies, and Caddis flies, in addition to the three types and their relations which still remain within the Order.

The old Neuroptera has now been broken up into a number of Orders most of which are Exopterygota.

(*a*) Ant-lions (*Myrmeleonidæ*) resemble dragonflies in general appearance but live in dry places and have larvæ and pupæ, i.e. four stages in the life-history.

The larvæ dig pits in dry sand and capture the insects which fall in.

(*b*) Alder flies (*Sialidæ*) have aquatic larvæ with segmented tracheal gills. These live in the muddy bottoms of ponds, etc., and come out of the water and bury themselves in the banks to change into pupæ.

(*c*) Lacewings (*Chrysopidæ*) are useful in the larval stage, as they feed upon aphides. They suck the blood of their prey and their mouth-parts are specially modified to that end.

6. **Mecoptera** (Scorpion flies), so called because the male has the apex of the abdomen enlarged and somewhat resembling that of the scorpion. Carnivorous in both larval and adult stages, feeding mostly or entirely upon insects and spiders.

Related to the Neuroptera.

7. **Trichoptera** (Caddis flies). An Order of aquatic insects. The eggs are laid on aquatic vegetation beneath the surface of the water and the larvæ build cases for themselves by fastening together with silk, various materials.

Larvæ of different species make different types of case, some using pieces of leaf or leaf and stick, or sand or gravel and shells of molluscs, even with the mollusc inside the shell. Pupation takes place beneath the water inside the case, and, shortly before the emergence of the adult, the pupa becomes active and escapes from the case, biting through the silken web which the larva spun over the mouth of the case just before it became a pupa. The pupa possesses a large pair of mandibles solely for the purpose of cutting through the silk.

The active pupa swims to the surface and there the adult escapes.

The mouth-parts of the adult are rudimentary and there are no mandibles.[1]

[1] To extract Caddis larvæ from their cases, drop them alive into boiling water and boil for one or two minutes. Take them out and allow them to cool and, with a pair of fine forceps, catch hold of the head and the larva will come out quite easily.

8. **Aphaniptera** (or Siphonaptera) (Fleas). Parasites of warm-blooded animals and, like the blood-sucking lice, wingless.

The adult is almost unique amongst insects in being compressed laterally instead of dorso-ventrally.

Unlike most external parasites, the flea does not fix its eggs to its host, but they fall to the ground and the larvæ feed upon any organic particles in the dust, in cracks in floors, the excrement, etc., in the chicken houses, birds' nests, moles' nests, etc. These larvæ are legless and somewhat resemble the larvæ of the simpler flies. It is probable that the two Orders had a common ancestry or that the fleas descended from the Diptera.

IV. DEMONSTRATIONS

Special notes connected with the third period in the syllabus

I. **Typical " Mandibulate " Mouth-parts,** i.e. Mouth-parts adapted for biting and chewing.

Slides : Blatta, Grylla, Carabid or Telephorid beetle.

Draw from any slide (1) a Mandible,
(2) a Maxilla,
(3) a Labium.

II. **Antennæ.**

Slides showing different types, e.g. Wasp or Carabid beetle (filamentous); Chafer or Dung-beetle (lamellate); Butterfly (capitate); Hydrophilid beetle (clavate); Curculionid beetle (capitate and geniculate); and examples of serrate and pectinate, e.g. Buprestid, Elaterid or Telephorid beetles.

III. **The Proventriculus of the Alimentary Canal :** the posterior part of the Stomodæum or fore-gut.

Slides : Grylla (House-cricket), Dytiscus.

It acts as a filter, allowing solid materials to pass into the mid-gut, but the backwardly-pointing "teeth" prevent solids passing forwards again, although they do not stop digestive fluids.

Draw a proventriculus.

IV. **Spiracles.**

Slides: Dytiscus, Larva of a Lamellicorn beetle, e.g. dung-beetle or chafer.

Dytiscus has a simple spiracle in which the opening is protected by projecting "fingers" of chitin fringed with hairs. Behind the spiracle is a "closing apparatus," by means of which the trachea can be squeezed and more or less completely closed. This consists of a chitinous band, a lever and a muscle. All three parts may be visible in one slide, but if the material has been treated with potash during the preparation, the muscle will have disappeared. The Lamellicorn larva has a "sieve-plate" type of spiracle, characteristic of the larvæ of all this large group of beetles, of which the adults are recognizable because they possess lamellate antennæ and tarsi with five simple segments.

Draw a spiracle of each type.

V. **Tarsi.**

May be composed of one or more segments and the segments may be simple or modified.

Slides. 1. Dytiscus, the large carnivorous water-beetle, has 5-segmented

tarsi which are simple in the female, but the anterior ones in the male are modified for holding the female during copulation, the three basal ones together forming a pad.

2. Cerambycid or Chrysomelid beetle. The tarsi are 5-segmented, but segment four is minute and is fused to segment five. Such a tarsus is characteristic of a large group of beetles, and as it was thought to be 4-segmented, the group used to be called "Tetramera."

3. Vespa or other Hymenopteron; anterior leg. Here the basal segment is modified and associated with a tibial spur to form a "antenna cleaner," the antennæ being frequently drawn through the gap between the spur and the tarsus for cleaning purposes.

4. Apis or Bombus; fore-, middle- and hind-leg of a worker Apis or of a worker or queen Bombus. Note the enlargement of the basal segment of the tarsus and, in the hind-leg, the enlargement also of the tibia.

The hairs of the bee's body collect the pollen from the flowers and the fore- and middle-tarsi brush this backwards on the underside of the body within reach of the hind-tarsi. These, by rubbing together, push the pollen on to the outer sides of the enlarged tibiæ, which are hollowed out to form "pollen baskets," and it is in these latter that the bee carries the pollen, made sticky with nectar or honey, back to the nest or hive.

Draw these types of tarsi and their associated structures.

V. A SYLLABUS OF AN ELEMENTARY PRACTICAL COURSE

(Two hour periods) worked upon the notes already given

1. Cockroach, External Characters (Lecture Demonstration).
2. " Dissection commenced.
3. " Dissection completed.

   Slides showing typical "mandibulate" Mouth-parts, Antennæ, Proventriculus, Tarsi, and Spiracles of a few insects. See special notes connected with this demonstration (p. 25).
4. Lepisma or Machilis, as an example of Apterygota, and Notonecta or Nepa, as a first example of Exopterygota (Imago and Nymph).

   Slides of Bug mouth-parts.
5. Dragonfly, Zygopterid imago and nymph.

   Demonstration of Apterygota (slides or specimens).

   Examples of Bugs and Dragonflies.
6. Beetle (Cockchafer or other Scarabæid), as a first example of Endopterygota, and Butterfly, with Caterpillar and Pupa.

   Examples of a few Beetles, Butterflies and Moths and slides of mouth-parts of Lepidoptera.
7. Wasp and Bee (Apis or Bombus), with larva and pupa.

   Examples of Hymenoptera and slides (5 or 6) showing the evolution of mouth-parts in that Order.
8. Fly (Gnat and Blowfly) and Gnat larva and pupa, and larva and puparium of Blowfly.

   Examples of Diptera and slides of mouth-parts of Culex and Musca or Calliphora.
9. The Orders of insects.

   Specimens and slides of Isoptera, Ephemeroptera, Anoplura, Thysanoptera, Neuroptera, Trichoptera and Aphaniptera.
10. General Revision.

NOTE. The demonstrations should consist of a very few specimens and these should, as far as possible, represent important points. Boxes full of specimens only confuse a student or make him give up trying to make anything out of them. A large number of the slides referred to should be provided, but some, the number depending on the speed at which each student works, should be made by the members of the class.

PART II

ADVANCED COURSE

I. THE BEETLE (DYTISCUS MARGINALIS)[1]

THE beetle given you is a species of Dytiscus (or Dyticus), Series Adephaga, subseries Hydradephaga, family Dytiscidæ.

The eggs are buried in the submerged stems of water plants, e.g. *Glyceria*; the larvæ are aquatic, coming to the surface at frequent intervals to renew their air supply. The larvæ leave the water and form a cell in the ground to pupate and the adult beetles return to the water, where they spend most of their time.

Note the flat oval shape of the body, the large elytra or "wing-cases" covering all the posterior part and the strong flattened and feathered hind-legs, the general form and the hind-legs being specialized for swimming.

Sexual differences

(1) The male can be recognized by the anterior tarsi, in which the three basal segments are enlarged to form a flat, more or less circular, pad with special "holding discs" beneath. In the female the anterior tarsi are simple.

(2) The male has smooth elytra; in the female they are fluted.

N.B.—The female in some species is dimorphic and the smooth male-like form is often the commoner. This type of female can be distinguished from the male by the simple anterior tarsi.

(3) The male, on the average, is larger than the female.

The Head. The head is flattened and the clypeus and labrum are clearly marked off and visible from above, i.e. the face is dorsal. In *D. marginalis* the clypeus is bright yellow and the labrum dull yellow.

The antennæ are 11-segmented, filamentous; attached, one in front of each eye and, in a state of rest, lie backwards beneath the sides of the head and thorax. (*N.B.*—Filamentous antennæ are characteristic of all Adephaga, which used to be known as "Filicornia.")

Examine the lower side of the head and note the median gular sclerite separating the two genæ and bearing the labium, the latter being small with

[1] These notes are suitable, except in small details, for any British species of Dytiscus and will also do for *Colymbetes fuscus*, and, in the main, will cover the Dytiscid group.

3-segmented palps; note the maxillæ, with 4-segmented palps, lying in a deep groove on each side of the labium and the large mandibles fitting between the maxillæ and the labrum. (The palp-like galeæ of the maxillæ are characteristic of the Adephaga.) The mouth-parts are of the usual "mandibulate" type, similar in general respects to those of the cockroach (see Fig. 13).

The Thorax. In the dorsal aspect, all that is visible of the thorax is:

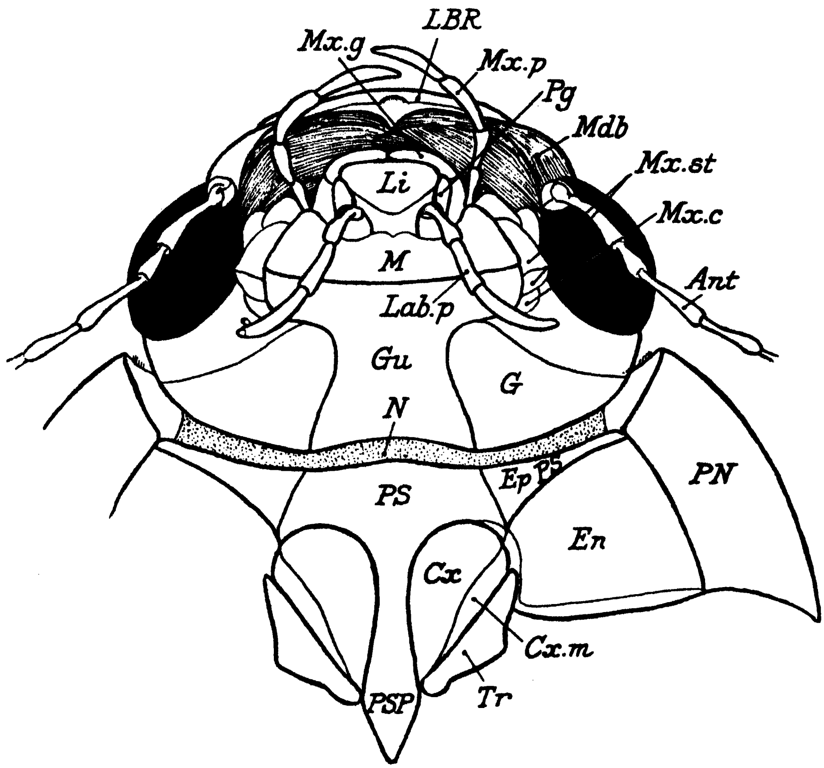

FIG. 13.—Dytiscus. Ventral view of head and prothorax.
Ant = antenna; *Cx* and *Cx.m* = coxa vera and coxa meron; *G* = gena; *Gu* = gular sclerite; *Lab.p* = labial palp; *LBR* = labrum; *Li* = ligula; *M* = mentum; *Mdb* = mandible; *Mx.p* = maxillary palp; *Mx.c, st, g* = maxillary cardo, stipes, and galea; *N* = "neck"; *Ep, PS*, and *En* = episternum, pleural suture and epimeron of pro-pleuron; *Pg* = paraglossa; *PS* = prosternum; *PSP* = prosternal process; *PN* = the overlap of the pro-notum; *Tr* = trochanter of leg.

(1) The pronotum, a large transverse sclerite and (2) the scutellum of the mesothorax, a small triangular median sclerite.

Immediately behind the pronotum are the large elytra, the anterior pair of wings, hardened so as to act as a shield to the back and to protect the second pair of wings which lie folded beneath them. In the membrane between the pro- and meso-thorax, on the sides of the dorsum, are the first pair of thoracic spiracles.

Insert a knife or needle between the elytra and gently prise up one and then the other. Now pin the insect down, dorsum up, with a pin through each side of the prothorax. Raise up the elytra and fix them in the position and manner shown in Fig. 14.

Note the position of the posterior (metathoracic) wings and the manner in which they are folded. Spread the two wings and fix them as shown in the diagram. The meso- and meta-thorax and the abdomen are now fully exposed.

Below each elytron, at its base and near the median suture, note the small wing-like "alula," once regarded as the true wing, the elytron being regarded as an enlarged tegula. The alula is merely a basal lobe of the anterior wing or elytron, possibly the jugal lobe or jugum.

The mesonotum is comparatively small. A dark transverse piece, the prescutum, carries the scutellum on its posterior edge and on each side of this is the scutum. The part which is apparently the dark posterior edge of the

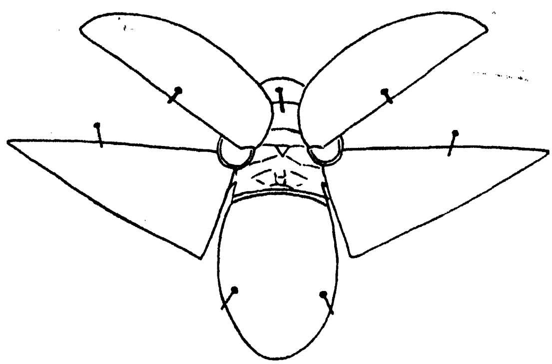

FIG. 14.

scutum is really the scutellum and carries at its outer extremities the axillary chords, while the scutum carries the posterior-notal-wing-processes (see Fig. 15).

On each side of the prescutum is the anterior-notal-wing-process, and the wing (elytron and alula) is carried on the two wing-processes, three small irregular "axillary sclerites" lying in the membrane between the two and articulating with one another and with the elytron (see Fig. 15). *N.B.*—The axillary sclerites are difficult to see in this segment since two of them lie partly beneath the prescutum and scutum and the third is closely attached to the elytron.

The membrane between the side of the mesothorax and the wing and in which the axillary sclerites lie is the "axillary membrane."

Place the point of a needle beneath the posterior edge of the scutellum and gently press it forward so as to expose the inter-segmental membrane connecting the meso- and meta-nota. In this membrane, on each side, is a small triangular sclerite, the "yoke plate," apparently peculiar to certain Coleoptera and perhaps representing the post-notum.

Draw the mesonotum, showing the axillary sclerites and chords, the base of the elytra, the alulæ and the yoke plates.

The metanotum is large and composed of the same parts as the mesonotum.

On each side is a large scutum divided into two scutal plates by a transverse furrow, a character peculiar to Coleoptera. In front of the scuta is the prescutum, with a backwardly-projecting bilobed process in the median line. The apices of this process reach to the posterior margin of the scuta. The

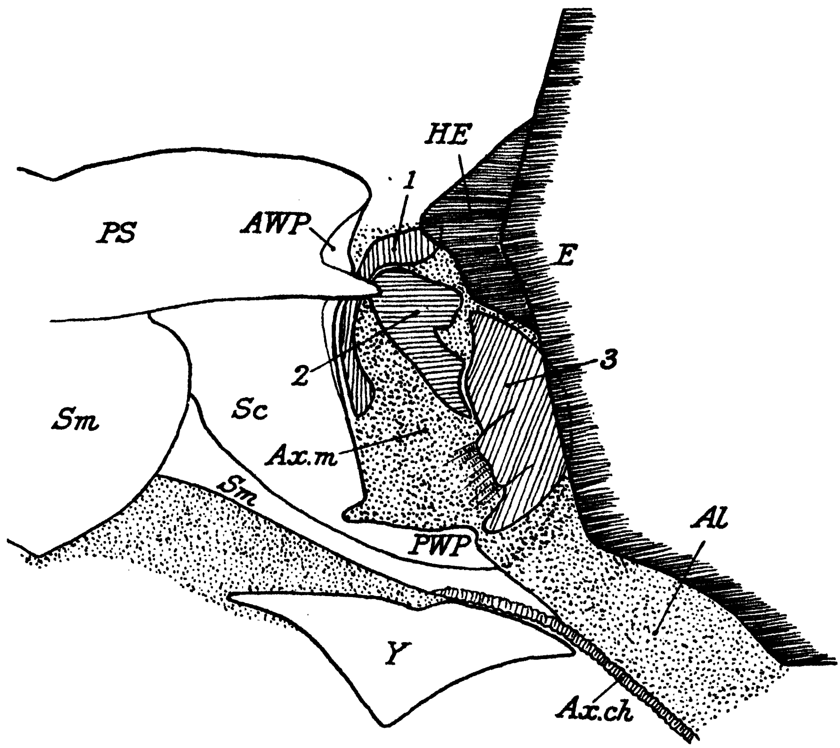

FIG. 15.—Dytiscus. Dorsal view of right half of mesothorax. 1, 2 and 3 axillary sclerites embedded in *Ax.m*, the axillary membrane running out posteriorly into *Al*, the "alula," bordered by the *Ax.ch*, axillary chord from the scutellum.

AWP and *PWP* = ant- and post-notal wing-processes; *HE* = hinge process of the elytron; *E* = the elytron; *PS* = prescutum; *Sc* = scutum; *Sm* = scutellum; *Y* = yoke plate, which is more or less vertical in the membrane between meso- and meta-nota.

prescutal plate bears a more or less triangular anterior-notal-wing-process on each side.

Behind the scuta is the scutellum with a forwardly-projecting process fitting in between the posterior horns of the prescutum. *N.B.*—This type of scutellum, cutting the scutum into two halves, is characteristic of Coleoptera.

Behind the scutellum is a narrow transverse piece stretching on each side beyond any other part of the metanotum. This is the post-notum (or post-

scutellum or pseudo-notum), consisting of a median and two small lateral sclerites, the latter being connected with the epimera of the pleura of the segment, which just appear in the dorsal view. The wings are attached to the metathorax by the axillary membrane bearing three axillary sclerites; (1) the largest, connects closely with the anterior-notal-wing-process; (2) lies outside 1 and fits into it; (3) is a long irregular structure lying outside both 2 and 1 and connecting with them, with the bases of the wing-veins and with the posterior-wing-process. Note the muscle-attachment on the body side of 3, a useful point for recognizing this sclerite in other insects.

The muscular apparatus of the wing is attached below these sclerites and

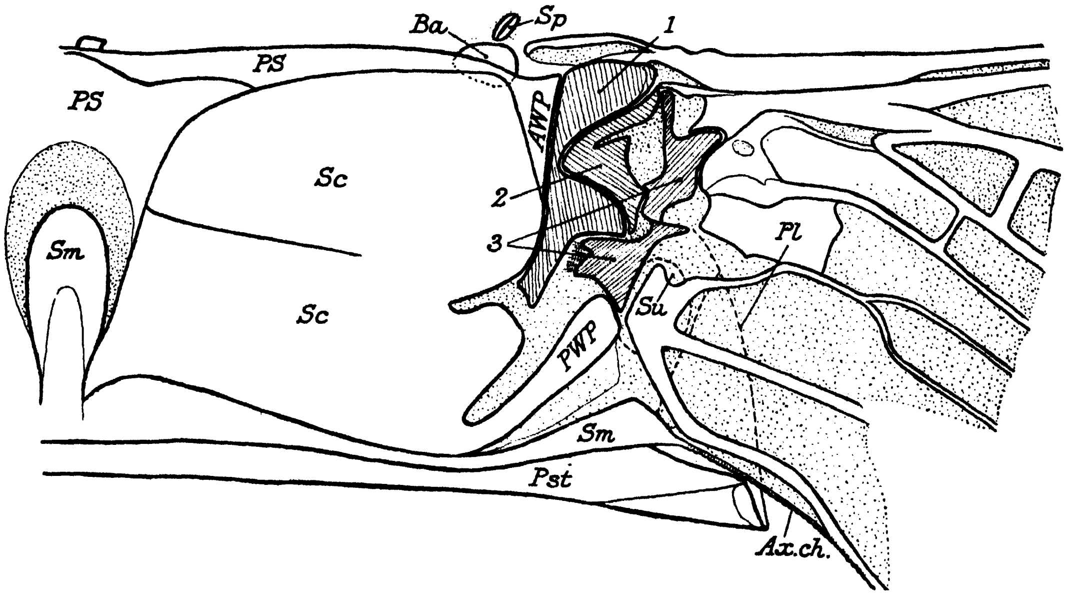

FIG. 16.—Dytiscus. Dorsal view of right half of metathorax.

AWP and *PWP* = ant- and post-notal wing-processes; *Ax.ch.* = axillary chord; 1, 2 and 3 = axillary sclerites; *Ba* = basalare and *Su* = subalare, the two epipleurites, the latter seen through the wing membrane; *Pl* = the edge of the pleuron, seen through the wing membrane; *PS* = prescutum; *Pst* = postnotum; *Sc* = scutum; *Sm* = scutellum; *Sp* = 2nd thoracic spiracle.

the bases of the wing-veins, though the main part of the wing movement is produced by changes in the shape of the thorax, for which the large vertical muscles in the meso- and meta-thoracic segments are responsible. At the base of each wing, rather nearer the median line of the body than the anterior-wing-processes, is a small yellow projection, the anterior epipleurite, the "basalare" (see Fig. 16).

Immediately in front of the anterior margin of the wing will be seen an edge of chitin which, on examination, proves to be a more or less vertical plate, the episternum of the mesothorax. In the membrane between this and the anterior margin of the metathorax and almost directly below the basalare, will

be seen the second thoracic spiracle, a slit-like opening in a small island of chitin (see Fig. 17).

Draw the metanotum, showing sutures, wing-processes, axillary chord and wing-base attachments.

The Abdomen, Dorsal aspect. Eight terga are visible, dark in colour, bordered on either side by the "pleural membrane" in which are eight spiracles.

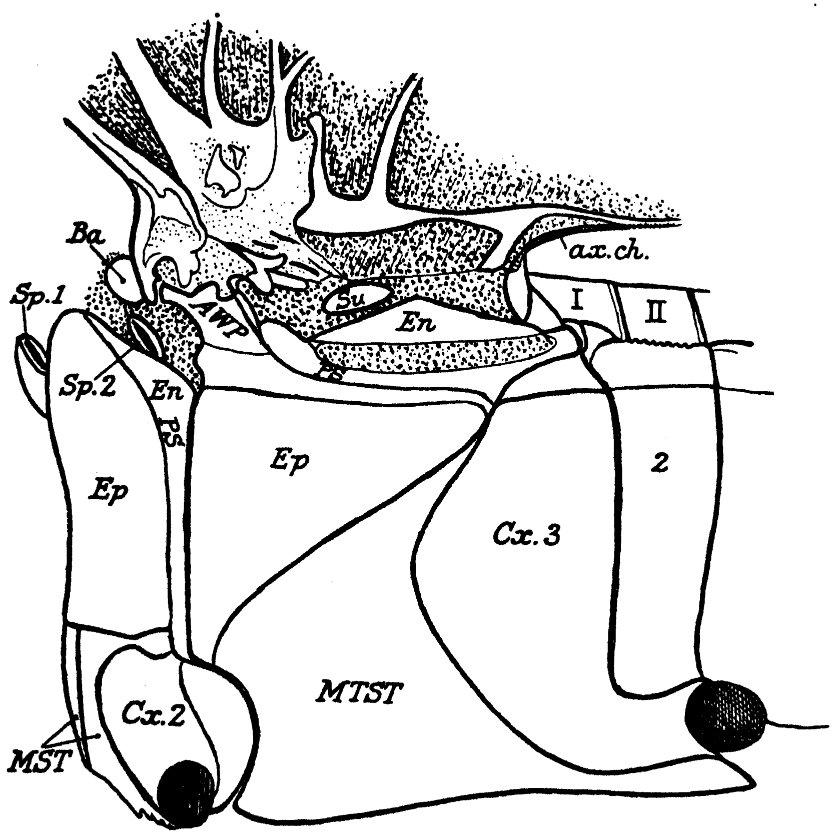

FIG. 17.—Side view of meso- and meta-thorax, the former with the elytron removed, the latter with wing spread upwards.

AWP = ant. pleural wing-process; *ax.ch* = axillary chord; *Ba* and *Su* = basalare and subalare, the metathoracic epipleurites; *Cx.*2 and *Cx.*3 = coxæ of meso- and meta-segments; *Ep* and *En* = episternum and epimeron; *MST* and *MTST* = sterna of meso- and meta-segments; *PS* = pleural suture; *Sp.*1 and *Sp.*2 = the 1st and 2nd thoracic spiracles; Roman and Arabic numerals = terga and sterna of abdominal segments.

Note the varying size of the spiracles, 8, 7 and 1 being the largest. Certain small dark longitudinal marks are visible in series on the abdominal segments. These are thickened parts of the chitin bearing muscle-attachments below. Note the depressed and transversely-corrugated margins, "epipleurites" of the apparent 1st but really the true 2nd sternum projecting upwards on each side of terga 1' and 2. When the elytra are at rest, they fit close over the

epipleurites of the sterna, except in the case of the second, where a slit-like gap is open on each side of the body, possibly in some way connected with respiration.

Ventral View of the Insect

Fix the insect down, ventral side up, by means of a pin inserted on both sides between the prothorax and the head, without penetrating either of these or the intersegmental membrane; with two other pins hold out the posterior legs and thus steady the insect.

The Head. The ventral side has already been examined.

The Thorax

The Prothorax. Note the prosternum, a narrow sclerite on the anterior edge of the segment, stretching across to the underside of the pronotum on each side. The prosternum bears a median, backwardly-projecting piece, the prosternal process, the apex of which fits into a groove on the mesosternum and just reaches the metasternum. On each side of the process are the coxal cavities and, outside these, the episternal plates, the only pleural pieces of this segment.[1]

Anterior legs. Note the coxæ with their outer side flattened to allow of the folding back of the trochanter and femur which, in a state of rest, lie in a transverse groove between the pro- and meso-thorax. In the male, note the short thick tibia and peculiar tarsus with flattened pad formed of the three basal segments and, on the underside of this pad, note the two large and numerous small "holding discs."

In the intersegmental membrane behind the prosternum, note the two small chitinous knobs.

The Mesothorax. The mesosternum is a small solid structure largely hollowed out posteriorly for the coxæ of the middle pair of legs. On each side of it lies the pleuron which faces more or less forwards instead of to the side. The pleural suture is easily seen, curving forward and outward from the base of each leg, having a quadrangular episternum in front and a triangular epimeron behind it. Note that this epimeron is a very narrow plate and is bounded posteriorly by the large triangular episternum of the metathorax (see Fig. 17). With a needle, gently raise the outer edge of the epimeron and the second thoracic spiracle will be seen.

[1] The above is the usual interpretation of the narrow sclerite, but in this, and in many other Dytiscids, there is a faint line which might be the remains of a suture dividing the so-called prosternum into a median and two lateral regions. These sutures rather suggest that the median part is the prosternum and that the laterals are the episterna of the pleura, a view which is supported by the fact that the posterior suture of these laterals, separating them from what has been regarded as the episternum, connect with the coxal cavity exactly where the pleural suture should be found. This would make the so-called episternum (or pleural sclerite) the epimeron (see Fig. 13).

The Metathorax. The metasternum is a large sclerite with a small anterior projection in the middle line over the bases of the middle coxæ and overlapping the backwardly-projecting portion of the mesosternum.

The lateral extensions of the metasternum are the "metasternal wings" and in some Dytiscid genera, e.g. Agabus, their form is of systematic importance. Note how the anterior border of the metasternum fits round the bases of the mesothoracic coxæ so that these coxal cavities are described as "open," i.e. they are not completely surrounded by their own segment.

Above the metasternal "wings" lie the "episterna," triangular in form. At the posterior angle of each episternum is a point which, in most insects, is the coxal process of the episternum which articulates with the coxa. In the Dytiscidæ, however, the posterior coxæ form a pair of large plates resembling sclerites, fitting in behind the metasternum and fused with it and with each other. On each side of the median line the coxæ project backwards to form the coxal processes. These are of systematic importance since, by their shape, the species can often be identified, e.g. in all our Britannic species of Dytiscus.

In order to see the epimeron of the segment the elytron must be raised and the insect viewed from the side. Find the point where the coxal process of the episternum would be if the coxa were not fused to the thorax, i.e. the posterior apex of the episternum, and note that part of the plate is bent upwards so that a small part of it lies in a more or less vertical position. At the anterior corner of this vertical part is the anterior-wing-process and from this point to the coxal process is a faintly-marked pleural suture.

The sclerite above this, with a membranous centre, is the epimeron (see Fig. 17). Above the epimeron, note an isolated, more or less circular "epipleurite," the subalare, a ventral supporting-plate for the wing-base.

The Abdomen. The six visible sterna call for no comment, excepting the first which is divided into two by the backwardly-projecting median region of the coxæ. (This sternum belongs to the 2nd segment, the true 1st being membranous or absent in all the higher insects.) The 6th (true 7th) sternum in both sexes is slightly emarginate and, concealed by the 6th, is another, bilobed and with a membranous patch. For further reference to the posterior segments, see notes on the male and female genital armatures.

Dissection

1. Remove the elytra by raising and gently twisting backwards and forwards and cutting at the base. The 3rd axillary sclerite will probably come away with the elytron; note, immediately below its place of insertion, a small vertically-placed sclerite, the epipleurite of the mesothorax. This assists in the support of the elytron. If pressed sideways with a needle it shows itself to be a triangular plate.

Examine the elytron, noting the incurved edge, the "epipleuron."

2. Pin the insect through the prothorax as before, dorsal side upward. Insert a pin on each side of the metathorax, just outside the 1st axillary sclerite and also insert one through each of the eyes so as to fix the head.

3. Cut through the pronotum forwards and backwards to the anterior and posterior margins in the lines of the two pins and carefully remove the large middle piece of chitin, freeing it from its attachments below with a sharp knife inserted under the posterior edge and worked forwards as the piece is lifted.

4. Clear away the terga of the meso- and meta-thorax by cutting along the sides and lifting up and freeing from the underlying muscles.

5. Remove the terga and pleural membranes of the abdominal segments, being careful to secure, with some of the spiracles, some part of the tracheæ attached to them, preferably choosing some of the larger spiracles. Place these pieces of material in alcohol for future examination.

In the prothorax, note a pair of "defence" or "repugnatorial" glands in the anterior region. Their ducts open on the under side of the anterior edge of the pronotum and they pour out a yellow milky fluid when the insect is attacked. Behind these glands the space is mainly occupied by the large muscles of the anterior legs.

In the mesothorax the cut ends of the muscles of the middle pair of legs are the most obvious structures.

In the metathorax lie a stout pair of longitudinal muscles, while the rest of the space is occupied mainly by enormous oblique muscles reaching from the tergum to the sternal phragma and controlling expansion and contraction of the upper surface of the segment. Their size is associated with the strain put upon the segment by the action of the wings which they assist in raising by their contraction.

Between the median longitudinal muscles and at the posterior margin of the segment can be seen the anterior end of the heart extending forward into the aorta, the latter dipping down between the muscles on to the surface of the œsophagus.

6. Clear away the exposed muscles in the pro-, meso- and meta-thorax by catching the cut ends, a few strands at a time, with the forceps and gently pulling.

The first object is to expose the œsophagus which lies in the median line; the second object is to expose the lateral-descending-depressor wing-muscles, small for the elytra, large for the posterior wings, attached below the axillary sclerites in the meso- and below the axillary sclerites and the bases of the wing-veins in the meta-thorax.

The Dorsal Sympathetic or Stomatogastric Nervous System. On the surface of the exposed œsophagus in the pro- and meso-thoracic region, note a small longitudinal "recurrent nerve."

(1) Trace this backwards along the œsophagus, clearing this back to its posterior extremity in or about the 2nd abdominal segment. Note that the nerve passes over to the left side in the metathorax and, almost at the posterior end of the œsophagus, enlarges into a triangular ganglion which gives off a number of nerves to the mid-gut.

(2) Trace the nerve forward to the head and open this in the following manner: With a knife, cut forward carefully from the occipital foramen on each side and a little inside the pins, just keeping clear of the eyes, and proceed as far as the clypeus; carefully lift out the central piece, freeing it from muscle attachments. The posterior part of the head is entirely occupied by the ends of the "flexor (abductor) mandibularis" muscles; the anterior part is occupied by fat body and by the ends of the pharynx-dilator muscles. Carefully clear away the muscles and fat so as to expose the œsophagus and the recurrent nerve.

In a line between the eyes lie the supra-œsophageal ganglia (the brain), the œsophagus dipping down beneath them and the nerve going with it.

Clear away very carefully in front of the brain and again recognize the œsophagus and recurrent nerve and note that, about half-way between the brain and clypeus, the nerve expands into the "frontal ganglion," from which several nerves go off, notably one on each side.

Follow these nerves and note that they turn backwards and enter the brain one on each side, just where a nerve leaves the brain and passes to the antenna.

Immediately behind the brain on each side of the œsophagus, note a small ganglion connected by a nerve and also connected with the recurrent nerve below the brain. This latter connection can be seen by pressing forward the brain. These ganglia innervate the aorta and the tracheæ of the head.

Behind these lateral ganglia on each side lies a small glandular body resembling a second ganglion. These two bodies are the "corpora allata" and are said to be ductless glands.

Draw a diagram of the dorsal sympathetic system.

The Alimentary Canal. Note how the œsophagus enlarges as it enters the abdomen and how, at the posterior edge of the metathorax, it is supported by a hard chitinous ridge to which are attached large descending muscles. This ridge is the edge of the post-phragma, the large apodeme or endosternite of the metathorax, which carries the great muscles of the swimming legs.

Carefully clear away the fat body covering the organs and trace the gut backward, following the œsophagus, which opens into the proventriculus in or about the 2nd abdominal segment.

The proventriculus is short and opens into the mesenteron or mid-gut which is covered throughout its length with numerous small mesenteric cæca (cf. with the mid-gut of a cockroach or grasshopper where six to eight large cæca replace the numerous small ones seen in this type).

The mid-gut is comparatively short and dips downwards towards the right, its posterior extremity being concealed by the coils of the small intestine (ileum) and the numerous branches, red in colour, of the four malpighian tubules. The small intestine is a long, thin, highly-convoluted tube round which the malpighian tubules are tangled, these coming off from the gut at the line of junction of the mid- and hind-guts. The small intestine commences on the right side of the body and ultimately enters the large intestine (colon), usually on the left side.

Carefully unravel the small intestine and note its entrance into the middle of the balloon-like colon, at the apex of which is a large transversely-marked cæcum. The colon runs directly back into the rectum. On each side of the latter note an anal gland, a long fine convoluted tube opening into a large sac from which a duct runs backwards to open beside the anus. (The two extremities of the chitinous hoop of the sternum of the 9th segment come close together below and on each side of the anus and the anal gland duct is attached to the end of this hoop (see Fig. 18).)

Draw a diagram of the alimentary canal with the anal glands.

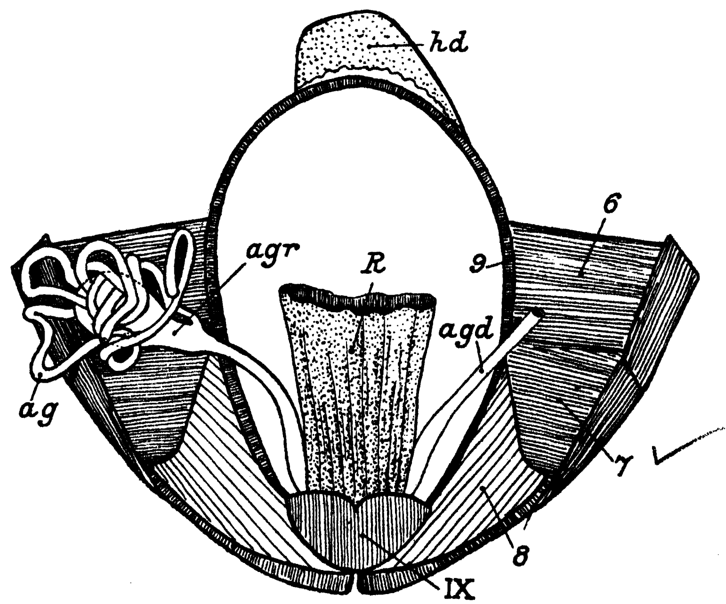

FIG. 18.—Dytiscus ♂. The anal glands. The terga, excepting the 9th (IX), have been removed. Arabic numerals indicate the sterna.
ag = anal gland; *agd* = anal gland duct, cut off; *agr* = reservoir of anal gland; *hd* = part of membranous "hood" which encloses the ædeagophore when at rest (see Figs. 22 and 23); *R* = rectum, cut off.

Cut out the proventriculus and preserve it for subsequent mounting and detailed examination (see notes on p. 50).

The Central Nervous System. Cut the œsophagus in front of the brain and, seizing it with forceps behind the brain, gently pull it backwards and then draw the whole gut backwards out of the body. The central nervous system now lies exposed.

The supra-œsophageal ganglia (brain) extend on each side into a large nerve which runs straight to the compound eye.

On each side of the gap from which the œsophagus has been removed is a lateral commissure connecting the brain with subœsophageal ganglia which

are held in position by the tentorial bridge. Immediately above the ganglia, note the transverse commissure running across between the lateral commissures. This is a small connective between two ganglia fused with the compound ganglionic mass or brain which indicates that the two ganglia which it connects were originally ventral to the œsophagus but have moved up, one on each side, leaving the connective in its original position. The subœsophageal ganglia lie in the posterior region of the head and the double nerve chord passes back to the prothoracic ganglia which lie in the prothorax. Behind these, and separated from them by a very short commissure, is a large ganglionic mass composed of meso- and meta-thoracic and 1st abdominal ganglia, the mass being held in position by overlying projections from the mesothoracic endosternite. (*N.B.*—The 2nd and 3rd thoracic ganglia are sufficiently separate to be recognizable, but not until the endosternite has been removed.)

The nerve chord now rises upward to mount upon the post-phragma (endosternite of metathorax), along the middle of which it lies in a groove, and in the groove are the other five pairs of ganglia of the system, the 2nd to the 6th abdominal, the last being a compound one including Nos. 6, 7, 8, 9, and 10 of the chain.

Thus the nerve chord is contracted and occupies very little of the abdominal region (cf. with Cockroach).

From the subœsophageal ganglia, nerves can be traced forward to the mandibles and immediately in front of these are a pair to the maxillæ. From between the latter, the labial nerves pass forward. The thoracic ganglia give off large nerves, and, from the group of abdominal ganglia, long nerves can be traced backwards to the various organs, nerves from the last pair of ganglia supplying the sexual organs, as in the cockroach.

Male Reproductive System and Genital Armature. At each side of the abdominal cavity, extending from about the 2nd segment to the 4th, is a highly-convoluted tubular testis. The testes are partly visible before the removal of the gut, but will be found intact after its removal, if this has been done carefully. Each testis is a single tube, but in preserved specimens it will seldom be possible to unravel it. From each testis there passes backwards a vas deferens, which lies posterior to it and is a highly-convoluted white tube very similar to the testis. These vasa deferentia ultimately dip down and pass towards the median line and each enters the base of a large tubular gland.[1] These two glands, the vesiculæ seminales, lie in various convolutions on the "floor" of the abdomen and their apices

[1] The size of the sexual organs varies according to the season of the year and the age of the insect. On the right side of the body cavity in Fig. 19 I have dotted in a testis from an individual killed in August shortly after emerging from the pupal stage.

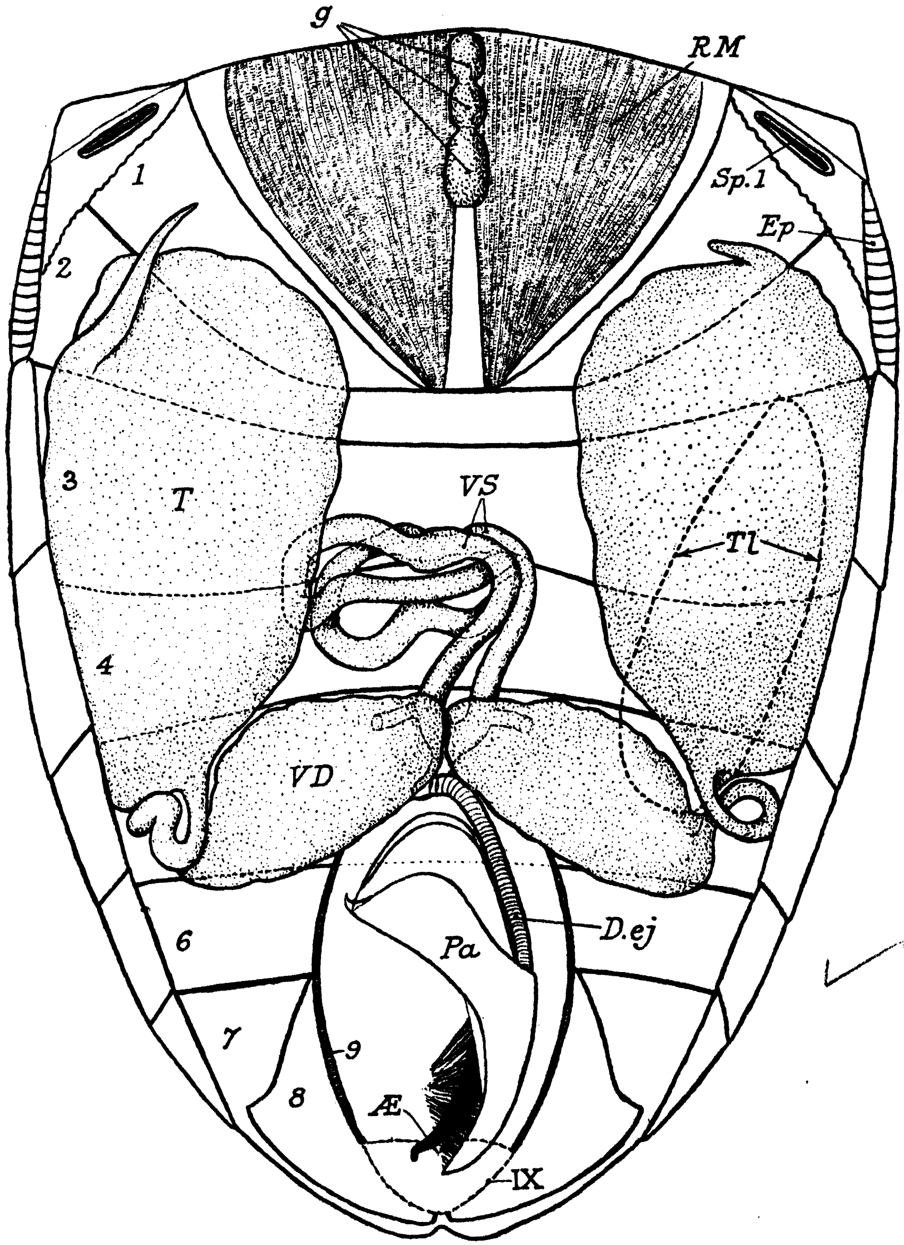

FIG. 19.—Dytiscus. Male reproductive system of mature individual, the convoluted tube of the testis (*T*) and the vas deferens (*VD*) being omitted.

On the right side *Tl*, in dotted line, is the size of a testis from an individual about a month after the pupal stage; IX = the dotted outline of the 9th tergum. Arabic numerals indicate the abdominal sterna. *AE* = apex of ædeagus; *D.ej* = ductus ejaculatorius; *Ep* = the corrugated epipleurite of the second segment, the epipleurites of the following segments are smooth; *g* = the posterior ganglia of the nerve chord, the nerves being omitted; *Pa* = the paramere, or lateral lobe, of the ædeagus; *RM* = muscles of hind legs; *Sp.*1 = the 1st abdominal spiracle; *VS* = vesiculæ seminales.

come together on the right side where they are held together by a ligament [1] (see Fig. 19).

A little below where the vasa deferentia enter, these glands unite together to form the ductus ejaculatorius.

The male armature. The ductus curls upwards and enters a large muscular mass. Cut beneath this mass and release it from the body, bringing with it the ductus and probably the vesciculæ seminales.

Clear away the muscles around the mass and expose a membranous and chitinous structure, the 9th abdominal segment. (*N.B.*—There are eight terga anterior to this segment and only seven sterna, as the 1st abdominal sternum probably does not occur in the Coleoptera.)

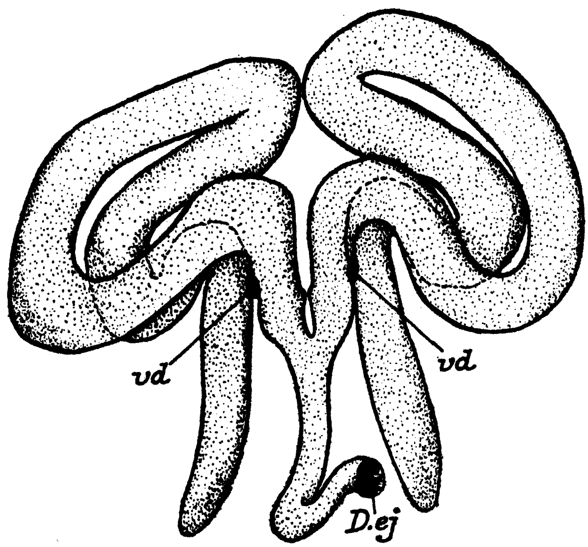

FIG. 20.—*Colymbetes fuscus.* Dorsal view of vesiculæ seminales, for comparison with the same organs in Dytiscus (Fig. 19).

D.ej = ductus ejaculatorius, cut off at the base of ædeagophore; *vd* = entrance of vas deferens.

This segment consists mostly of membrane, the tergum being a small plate at its posterior extremity (under which plate is the anus) and from each side of the tergum there passes forward and downward an arm of the chitinous hoop which represents almost all there is of the sternal sclerite.

Turn over the mass so as to see the ventral side and note a broad plate of chitin occupying part of that side to the right of the median line. This has been called the "oval piece" and represents the rest of the sternal sclerite (see Figs. 21, 22 and 23).

Note that it is almost independent of the hoop.

Within this segment (the last recognizable one, since the anus opens immediately posterior to it) lies the sexual armature which consists of a basal piece (in the form of a strut), a pair of lateral or accessory lobes (parameres) and a median ædeagus, analogous to the penis.

The whole armature is sometimes called the ædeagophore.

Carefully remove the 9th segment, noting the position of the armature within it, i.e. how it lies and which side uppermost. The armature lies on its

[1] The convolutions seem to be constant for the species, but they vary in different genera and, perhaps, in different species. They are different in *Colymbetes fuscus* from what they are in Dytiscus (see Fig. 20).

side. The ædeagus, the base and apex of which can be seen, is a curved structure and it lies with its concave side towards the left, the concave edge being its true dorsal side.

As the 9th segment is being removed, note a flat chitinous strut, widened anteriorly and posteriorly, lying on the right side, its long axis parallel to the median body line. This is, in its posterior broader part, the basal piece which, in most Coleoptera, is a large shield-like sclerite covering the ventral side of

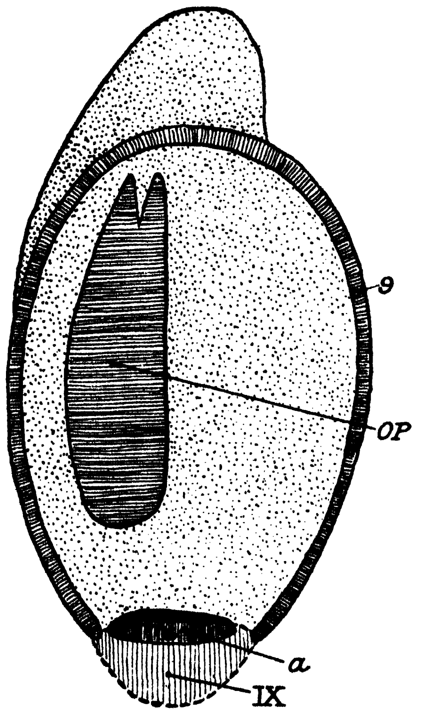

FIG 21.—Dytiscus ♂. Ventral view of 9th abdominal segment.

a = anus; IX = under-side of 9th tergum; most of the sternum is membranous, the chitinous hoop (9) and the oval piece (*OP*) being the only thickened parts.

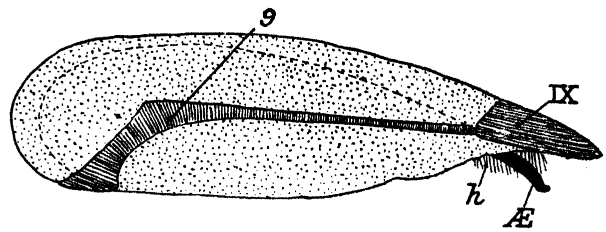

FIG. 22.

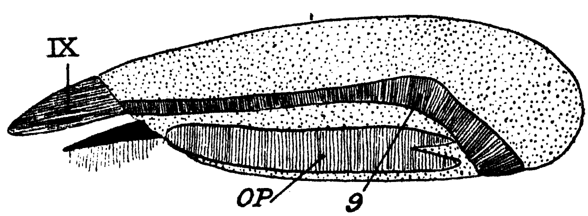

FIG. 23.

FIGS. 22 and 23.—Dytiscus ♂. Left and right side views of the 9th abdominal segment.

Æ = the apex of the ædeagus and *h* = the hairs of the parameres; IX = the 9th tergum. The sternum is mostly membranous, but 9 = the thickened hoop and *OP* = the oval piece.

the base of the ædeagophore. The anterior, narrower part is *within* the segment and is a long forwardly-projecting apodeme for the attachment of muscles connected with the extrusion of the ædeagophore (see Figs. 24, 25 and 26, and the notes in explanation of them).

Remove the sheath and expose the ædeagus enclosed between its lateral lobes. Note the form of the lobes with the strong feathering along the dorsal side near the apex and note that the lobes are united by a membrane almost to their apices, the membrane being on the convex (ventral) side of the ædeagus.

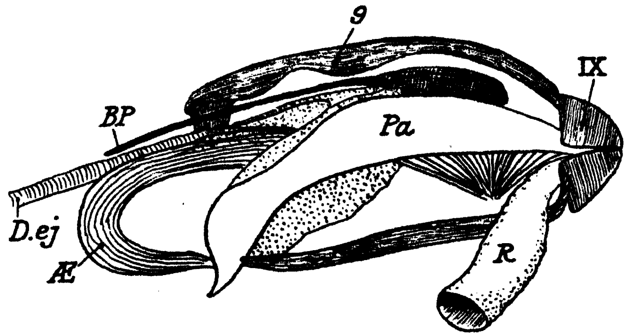

FIG. 24.

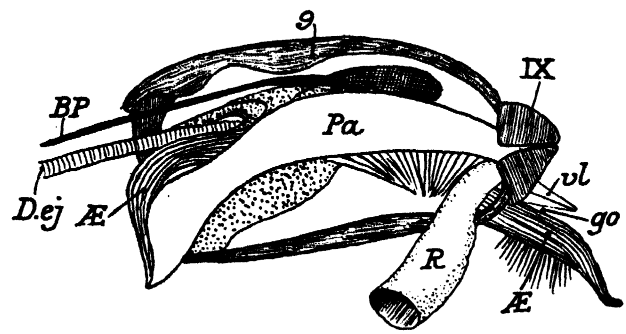

FIG. 25.

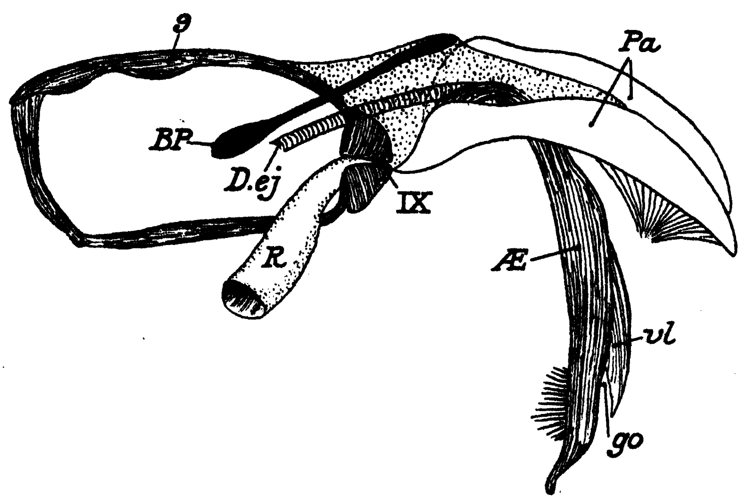

FIG. 26.

FIGS. 24, 25 and 26.—Dytiscus ♂. The 9th abdominal segment and its contents boiled in potash, to show the position of the ædeagus when at rest (Fig. 24) and when partly projected (Fig. 25) and when almost fully extended (Fig. 26). The view is from above, the ædeagus when at rest lying upon its left side in the segment. *Æ* = ædeagus; *BP* = the basal piece of the ædeagus (the strut); *D.ej* = ductus ejaculatorius; *go* = gonopore; *Pa* = the lateral lobe (paramere) of the ædeagus; *R* = rectum; IX = tergum of the 9th segment; 9 = the chitinous hoop of the 9th sternum; *vl* = the ventral lobe of the ædeagus, the concave edge of this organ being the dorsal side; note that the base of the ædeagus turns upon its hinge at the base of the parameres before the whole ædeagophore moves outward.

(*N.B.*—This connection of the lateral lobes does not exist in *Colymbetes.*) Cut out the ædeagus and note the strongly-hooked base, immediately in front of which the ductus enters a deep groove which runs almost to the apex of the organ on its ventral (convex) side. Note that the groove is covered in for most of its length by a pointed "tongue," between which and the main lobe is the opening of the ductus.

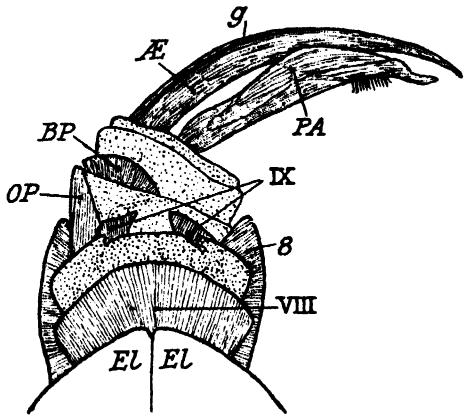

FIG. 27.

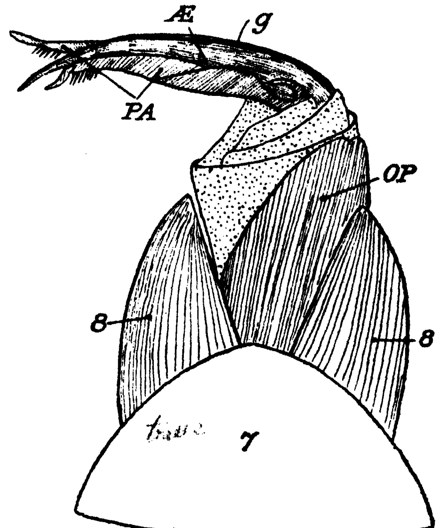

FIG. 28.

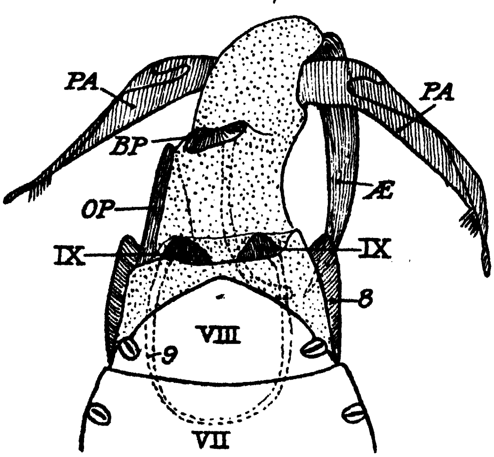

FIG. 29.

FIGS. 27, 28 and 29.—*Ilybius ater* ♂ (Dytiscidæ), apex of abdomen with the ædeagus partly protruded in Figs. 27 (dorsal) and 28 (ventral), and fully extended in Fig. 29.

AE = ædeagus; *BP* = basal piece (strut); *El* = apex of elytron; *g* = groove in ventral (convex) face of ædeagus, in which runs the ductus ejaculatorius; *OP* = oval piece; *PA* = paramere (lateral lobe) of ædeagus. Roman numerals indicate terga, Arabic numerals indicate sterna.

The form of the ædeagus and of its lateral lobes is often of considerable systematic importance.

The action of the armature. In copulation, the 9th segment projects from its position within the 8th and the ædeagophore projects from the 9th.

In extending, the ædeagophore revolves on its axis through 90° until the true dorsal (concave) side becomes ventral. The base of the ædeagophore then bends downwards and forwards so that the dorsal side becomes uppermost as it enters the vagina of the female (see Figs. 27, 28 and 29).

Female Reproductive System and Genital Armature. Open the female from the dorsal side as usual, from the anterior edge of the mesothorax to the last visible abdominal segment and clear away the thoracic muscles and the heart and fat body in the abdomen. In the abdomen the two ovaries will be seen lying one on each side. Note that each ovary is composed of a number of egg tubes, ovarioles, and these all taper off anteriorly and end each in a fine ligament. The ligaments from all the ovarioles form a common ligament for each ovary and these common ligaments may be seen lying one along each side of the œsophagus as far forwards as the phragma between the pro- and meso-thorax, where they are attached.

(*N.B.*—If the specimen is well preserved and not too young, the anterior part of the ovarioles will show the ova alternating each with one or more nutrient cells. Farther down the tubes, where the ova are larger, the nutrient cells are diminished in size. This type of ovary is known as "polytropic." See p. 80 and Fig. 45.)

Remove the alimentary canal, cutting out the proventriculus and putting it into alcohol for future examination.

Follow down the ovaries posteriorly, noting that all the ovarioles of one ovary unite at a common point to form a short oviduct which almost at once fuses with its neighbour to form the "common oviduct," or "uterus." [1]

Overlying the uterus is the basal part (towards the head of the insect) of the 9th abdominal sternum with its chitinous framework and membranous centre. Note the vaginal tube coming into this 9th segment over the right side at the anterior end (towards the head) of the sternum and note also the pair of nerves entering, one on each side of the segment, a little posterior to the vaginal tube. Trace these nerves forward and note that they are the last pair from the last abdominal ganglia (see Fig. 30).

Note the anal glands coiled up on each side, outside the framework of the 9th sternum, i.e. in the 8th segment.

Recognize the anus immediately beneath the tergum of the 9th segment, the pair of small dark sclerites joining the two chitinous arms of the sternum. The anus normally lies in the 10th (or 11th) abdominal segment, which is here represented only by the membranous anal ring.

Note the powerful muscles attached to the anterior end of the 9th sternum and passing backwards on each side to the 8th sternum, for projecting the 9th segment out of the 8th during the process of oviposition.

Clear away these muscles and the anal glands and note the sternum of the 8th segment. Now raise this sternum by inserting a lever under its free (posterior) edge, noting the muscle-attachment between it and the 7th sternum, and cut all attachments so as to free the 8th sternum, with

[1] Cf. Grasshopper, in which there is on each side a long oviduct receiving the ovarioles of the ovary along one side.

the 9th segment and the enclosed gonapophyses, from the rest of the body; lift this out, breaking off the ovaries near their bases, but do not damage the uterus.

Examine the uterus and note the vaginal tube coming from it; also the short "bursa copulatrix" which lies on this tube, just by its point of union with the uterus.

The bursa is said to receive the ædeagus during copulation and it probably acts as a spermatheca, holding the spermatophore until the fertilization of the eggs. Turn the removed mass upside-down so as to expose the ventral view of the 8th sternum and note that it is completely divided into two

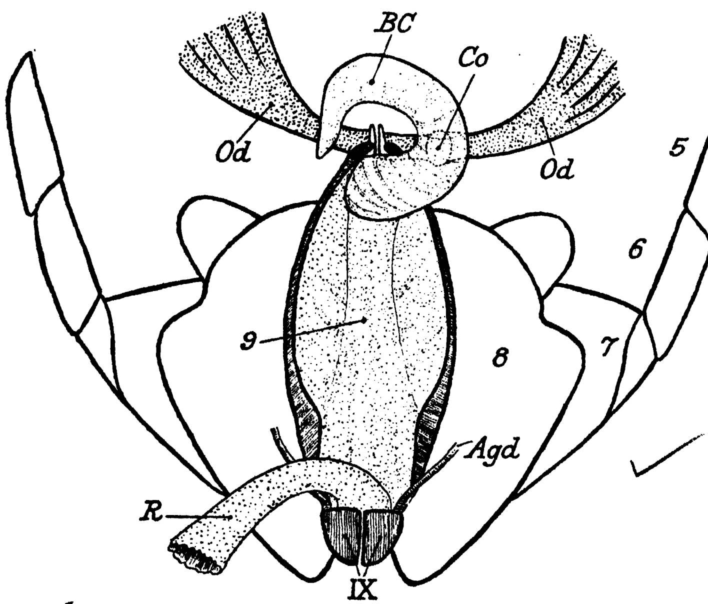

FIG. 30.—Dytiscus ♀. Internal view of the apex of the abdomen seen from above.

Agd = duct of anal gland; *BC* = bursa copulatrix; *Co* = the point at which the oviducts (*Od*) unite to form the common oviduct or uterus, indicated by dotted lines; *R* = rectum cut off and turned back; IX = 9th tergum; 9 = the 9th sternum with strongly chitinized side pieces and a membranous centre capable of considerable expansion. Other numbers indicate other sterna.

halves by a longitudinal slit. Note also the large membranous region in this sternum.

Cut away the connection at the base of the two halves of this sternum and pin out these halves on each side so as to expose the gonapophyses (which take the form of a piercing ovipositor) lying above, i.e. ventral to, the membrane of the 9th sternum and hinged between the posterior ends of its divided frame. Note that the ovipositor consists of a dorsal piercer which encloses a ventral lobe and between these two parts opens the vagina.

(*N.B.*—The female genital aperture is behind the 9th abdominal segment, its normal position in the Coleoptera, though, in the majority of insects, it is

behind the 8th. The number of abdominal sterna in the female is the same as in the male (see Figs. 31 and 32, showing lateral and posterior views of the 9th abdominal segment and the ovipositor in a state of rest).)

Split the ovipositor in the median line and note the vaginal aperture.

The action of the parts. In copulation there is apparently very little movement of the parts, but, in oviposition, various changes in the relative positions takes place. The 7th sternum is depressed and the ovipositor (which, at rest, lies against the membrane of the 9th sternum) projects out through the median slit between the two halves of the 8th sternum, the base of which projects out from its position in the 7th segment, while the apex retains its relationship with the 9th tergum. The 8th sternum ultimately stands almost perpendicularly, and, between its halves, the anterior end (the end which, when at rest, is towards the head) of the 9th sternum passes out, carrying the ovipositor in front of it, the posterior part of the chitinous ring of this sternum bending strongly round at the points of junction with the tergum, the latter turning over on itself.

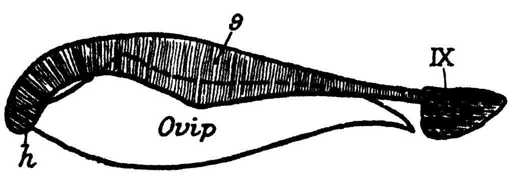

FIG. 31—Dytiscus ♀. The 9th abdominal segment with the ovipositor, to show the position of the parts when at rest.

Ovip = ovipositor; *h* = the hinge of ovipositor to the 9th sternum.

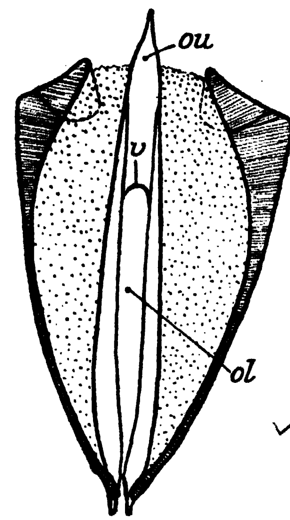

FIG. 32.—Dytiscus ♀. Segment 9 of the abdomen with the ovipositor, seen from behind or below.

ol = lower lobe of ovipositor while *ou* is the upper lobe, *v* being the vulva.

This revolution of the 9th sternum gives the ovipositor first a downward thrust, during which the piercer bores into the plant-tissues, then a backward thrust, during which the course of the piercer changes to become parallel with the surface, so that the hole bored has a curved shape (see Figs. 33 and 34).

When the ovipositor reaches the extreme limit of its thrust, an egg passes down and is left in the hole as the piercer is withdrawn.

SPECIAL POINTS

The Spiracle and Spiracular-control Apparatus. From the pleural membrane of the abdominal segments, carefully cut out two of the larger spiracles, preferably the 7th or 8th, with the adjoining pieces of the sclerite attached. Mount one so as to show the upper (outward) side and one so as to show the underside.

(*a*) In the first, note the long oval form and the structure, consisting of a firm chitinous ring, the "peritreme," bearing on its inner edge a number of chitinous rods covered with hairs and so arranged that there is a long narrow slit between the apices of the rods from each side. The rods are all thickly feathered and thus act as an efficient filter to the air as it passes in.

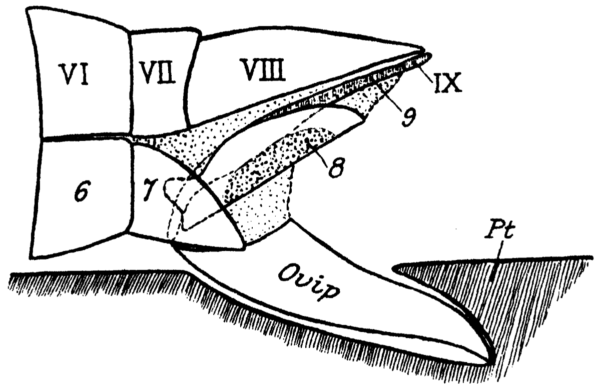

FIG. 33.

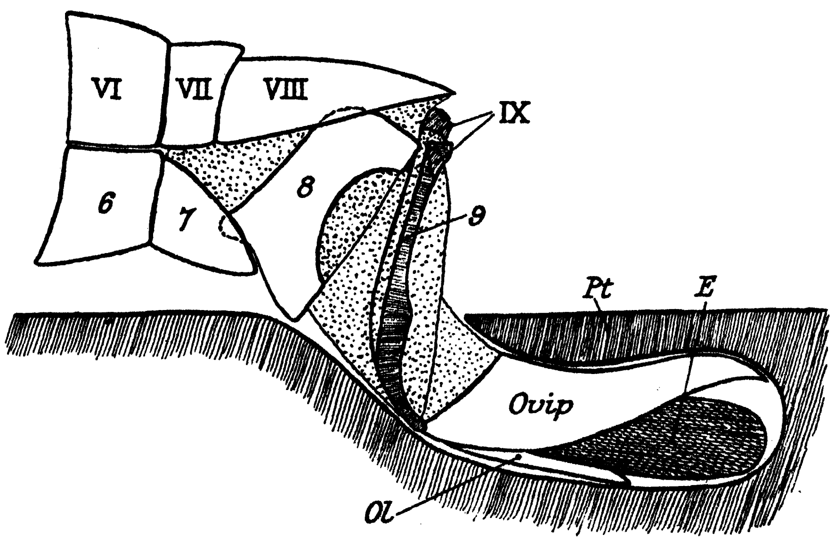

FIG. 34.

FIGS. 33 and 34.—Dytiscus ♀. The movements of the ovipositor during oviposition. *Ovip* = ovipositor; *Ol* = ventral lobe of ovipositor; *Pt* = plant tissue into which the ovipositor is boring; *E* = egg leaving ovipositor. In Fig. 33 the ovipositor is partly, and in Fig. 34 fully, exserted.

Draw a general view of a spiracle.

(*b*) In the second, note a small elbowed sclerite with one arm, the lever, projecting at right angles to the long axis of the spiracle, and the other, the band, running to one end of the chitinous ring to which it is fastened. On the opposite

side of the lever from the band note the occlusor muscle, inserted near the base of the sclerite, i.e. the part from which both lever and band project, and having its origin on the ring near the end. At the extreme apex of the lever and at right angles to it is a thin chitinous rod, the bow, embedded in the membranous tube running inwards from the chitinous ring of the spiracle and leading to

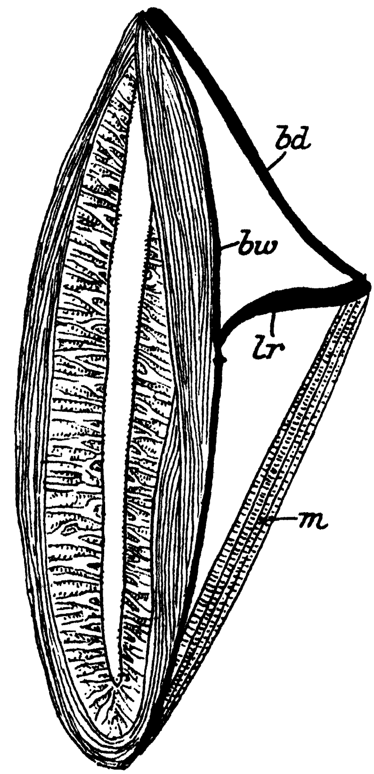

FIG. 35.

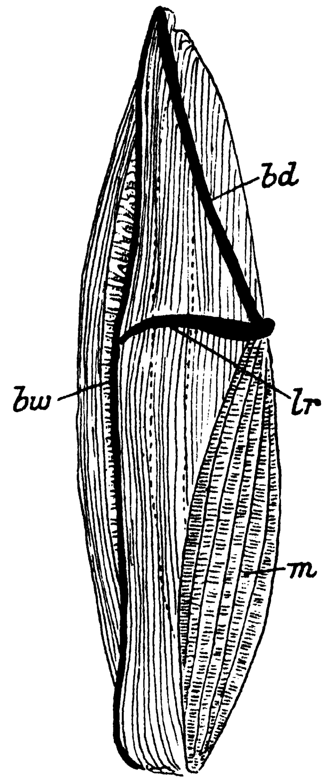

FIG. 36.

FIGS. 35 and 36.—Dytiscus. View of an abdominal spiracle from the inner side, to show the closing apparatus and its method of working.

bd = the band; *bw* = the bow and *lr* = the lever; *m* = the closing muscle. Fig. 35 shows the spiracle open; Fig. 36 shows the spiracle closed.

the atrium from which the tracheæ diverge. In a state of rest this bow lies so that there is a clear passage from the spiracle to the atrium, but, by contraction of the occlusor muscle, the lever moves forward and the bow, carrying the wall of the tube, is pushed across until it closes the aperture beneath the spiracle by squeezing the tube (see Figs. 35 and 36).

The Proventriculus. Open the posterior end of the œsophagus and note the eight chitinous plates, four larger main lobes and four smaller secondary ones, forming the anterior end of the proventriculus. The main lobes overlap the secondary ones and are fringed with hairs.

Split the proventriculus down one side and spread it out. Note the teeth situated beneath the apices of the secondary lobes and the strong circular muscles outside the teeth, for the purpose of closing all the lobes on a central point.

Boil the whole structure in strong potash for a few minutes, remove all remaining muscle-tissue and mount in canada balsam.

Action of the parts. Food can pass through the proventricular valves from the œsophagus to the mid-gut, but the valves are so situated, dipping towards the centre, that they will not allow solid particles to pass in the opposite direction. The secondary lobes can be slightly separated from the primary so that fluids can pass forwards from the mid-gut to the œsophagus, the fringed edges of the main lobes acting as efficient filters. Food is retained in the fore-gut where it is acted upon by the mid-gut juices and by the salivary gland secretions, in insects where these exist. (*N.B.*—There are no salivary glands in Dytiscus.)

Digestion is carried to a certain point in the fore-gut and then the material passes through the proventricular valves which crush any large, previously-undigested particles, into the mid-gut where digestion is completed and absorption takes place.

The Endoskeleton. Fix down the specimen in the usual way, removing the terga of the thorax and abdomen and the top of the head-capsule as before. Remove all the organs of the body so as to leave only the endoskeletal structures.

In the head, note the tentorium, reaching from the side of the occipital foramen to the front of the head on each side of the median line. Note the deep lateral pieces in the posterior region, between which lie the subœsophageal ganglia beneath the tentorial bridge. Note the anterior "wings" of the tentorium running up on each side of the framework of the mouth. In the thorax, note the small endosterni at the posterior edge of the prothorax and the larger ones in the same position in the mesothorax, the latter with lateral "wings" and also with anterior side structures passing to the front edge of the sternum. Note the upward projections of the pro- and meso-thoracic endosternites which meet over the space occupied by the nerve-chord and thus form a neural foramen.

The endosternite of the metathorax is a remarkable complex of plates and struts. Note the large postphragma with its two pairs of "wings," one pair fixed at their apices to the point on the metasternum at which, in most insects, the coxal joint lies, the posterior pair being lightly joined to a large upstanding posterior plate.

Note the median longitudinal plate on the metasternum and the two lateral longitudinals, one on each side of the base of the posterior phragma. Note also the smooth curved endosternite on the posterior edge of the metasternum on each side of the medial line and reaching to the extreme point of the "wing."

Remember that these apodemes are fixed points to which are attached the large thoracic muscles which control the movements of flight, walking and swimming.

IA. THE LARVA OF DYTISCUS

THE description here given is that of the larva of *Dytiscus marginalis*, the specimens having been grown from eggs laid by bettles in captivity, but, so far as I know, the larva of any British species will be suitable for this work, although there may be details in which these notes will not be correct. For instance, the shape of the head of the larva of *D. punctulatus* differs from that of all the other British species, being somewhat parallel-sided instead of moderately triangular, and this seems to be the only character for distinguishing this larva in the field. All the other larvæ are very similar in appearance and are not easily distinguished from one another.

EXTERNAL CHARACTERS

The larva is aquatic, spending its whole life in the water but coming to the surface at intervals to renew its air supply. It is of the "Campodeiform" type, its shape resembling, more or less, that of Campodea, one of the Thysanura, the most primitive Order of Insects.

Its form is well suited for moving through the water, which it does by the action of its legs, which are "feathered" for this purpose. The head is broad and flattened, contracting behind into a well-marked "neck." The prothorax is large, but the following nine segments in dorsal aspect are very much smaller. The last abdominal segment, the pygidium, is long and tapers away almost to a point, and it and the 7th segment have lateral fringes of hairs which act as lateral rudders. The feathered anal cerci may also act in the same way, but their chief importance seems to be that they bear sensory organs which are of use when the "tail" has to be brought to the surface-film for respiratory purposes.

The Head. Examine the dorsum, noting the two epicranial plates, separated by a median suture, and the fronto-clypeal-labral plate, the latter showing faint traces of transverse sutures. Each epicranial plate bears, laterally near its edge, six ocelli. Note the slender antennæ in front of each group of ocelli, the number of segments depending upon the age of the larva, six being the full number found in the third and final stage. Note the position of rest of the long, curved and pointed mandibles across the front of the head and more or less beneath the labrum, the left generally overlying the right.

Immediately in front of the antennæ and behind a lateral projection of the frons, note the dorsal articulation of the mandibles.

Turn over the insect so as to see the ventral side of the head, and note the

thickened ring of chitin surrounding the base of each mandible and the socket, in this ring, carrying the ventral mandibular articulatory process. Turn the insect on its left side for a lateral view of the head and move the right mandible backwards and forwards, noting that it moves on the dorsal and ventral processes, steadied above by the lateral projection of the frons, and that it can only move in one plane. Note also the small posterior projection of the mandible on which is inserted the extensor mandibularis (abductor) muscle.

Holding the insect in the same position, examine the inner face of the left mandible and note the groove running along the concavity. In the groove lies a fine transparent tube opening anteriorly just beneath the apex of the mandible and posteriorly on the dorsal surface just before the base. In order to see this latter aperture, the mandible must be moved outward.

Once again turn the insect ventral side up and note the filamentous form of the maxillæ, composed of eight segments, a long basal one bearing a short second and also a small spur. The second bearing a shorter third, after which the segments are long, short, long, short and long.

The labium consists of a small basal piece bearing two 2-segmented palpi. (*N.B.*—In almost all beetle larvæ the labial palp has only two segments.) On the ventral side of the labrum, note two membranous patches, probably gustatory in function.

The Thorax. The upper surface of all three segments is occupied by a large tergum which extends well down the sides. Note the extensive membrane between the segments allowing for considerable movement. Examine the ventral side and note the large sternal sclerite of the prothorax, the only thoracic sternal plate. Note the three pairs of legs.

Examine one of these and note the long backwardly-turned coxa, the 2-pieced trochanter, the femur, tibia and 1-segmented tarsus bearing a pair of claws at its apex. At the base of and external to each leg, and buried in a fold of the membrane, are the two pleural sclerites, the anterior or episternum and the posterior or epimeron. On the membrane between the episternum and the tergum of the mesothorax, note the small slightly-projecting spiracle, and, in the same position on the metathorax, note the small spot representing the 2nd thoracic spiracle.

The Abdomen. The abdominal segments are separated from one another by a fold of membrane, and, on each side of each tergum, is a membranous fold, so that each segment and the whole body is capable of much expansion and of free lateral movement. On the sides of the terga of the first seven segments is a small spiracle, that in the 7th being below the lateral fringe of hairs. At the apex of the 8th segment, immediately beneath the posterior edge of the tergum, is a pair of large slit-like spiracles. These are the only functional ones in the larva, all the others being closed by a layer of thin membrane, which easily ruptures in pickled and handled specimens.

The only functional spiracles being at the posterior end of the body, the larva is described as being metapneustic.

Note below the spiracles, a small median "suranal" plate, the 9th tergum, below which is the anus. The ventral view of the abdomen shows little worthy of remark except the absence of sternal sclerites, the whole region, except the last two segments, being membranous (see Fig. 37).

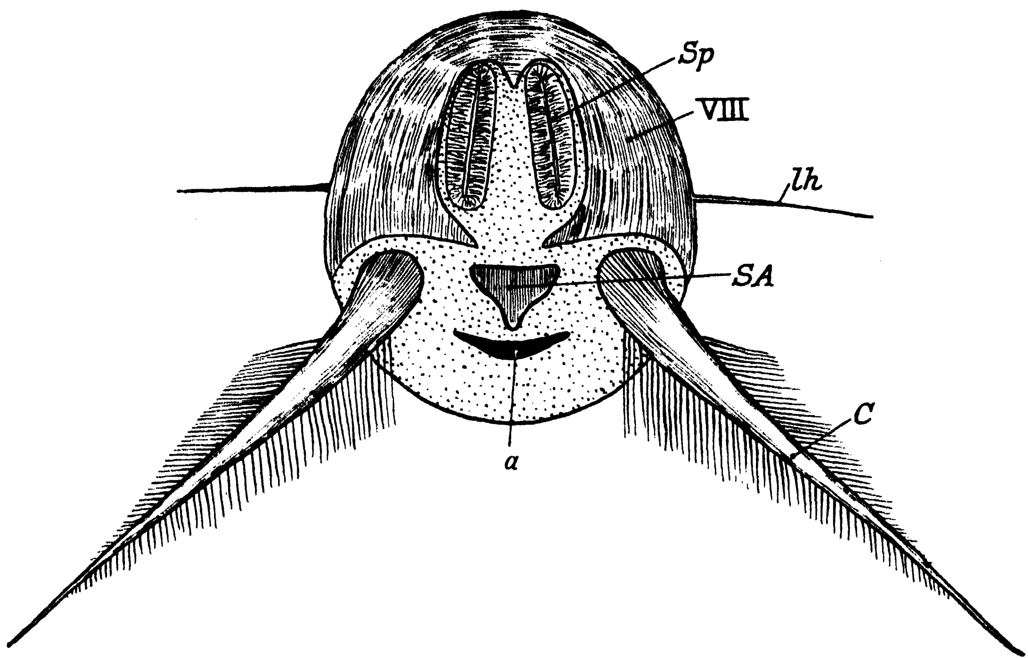

FIG. 37.—Dytiscus larva. Posterior end of abdomen.
a = anus; *C* = cercus; *lh* = lateral row of hairs; *SA* = suranal plate; *Sp* = spiracle; VIII = the 8th abdominal tergum.

DISSECTION

Open the insect by cutting along the mid-dorsal line from the prothorax to the last abdominal segment, and also open the head in the median line. Now pin out, removing the whole of the upper side of the head without damaging the eyes, and pinning just behind the eyes. Turn back the divided terga of the segments and pin out, noting the strong intersegmental longitudinal muscles.

General Points. In the mid-dorsal line note the heart, reaching forward to about the mesothorax where it narrows down to the aorta, which can be traced forward along the œsophagus to the point where it disappears beneath the brain. Note the numerous dark-coloured tracheæ, especially the two lateral trunks extending forward from the posterior spiracles. These trunks give off large branches to the gut in the 6th and 7th abdominal segments, and themselves divide into two large branches in the mesothorax, these passing forward into the head.

In the head, note the powerful flexor (adductor) mandibularis muscles situated, as in the imago, in the posterior-lateral region, and also the large pharyngeal muscles which work the pharyngeal pump, as in all suctorial insects. Just behind the pharyngeal muscles note the small brain, and, from it, the group of optic nerves going off on each side to the ocelli. Below and in front of the base of these nerves may be seen the anterior lobes of the brain, from which the antennal and labral nerves may be traced to their respective organs.

Very carefully clear away the adductor muscles and the abductors (extensors) which lie just outside and ventral to them. Also remove the pharyngeal muscles, noting that as the longitudinal ones are removed, circular ones surrounding the pharynx become visible.

The Dorsal Sympathetic Nervous System. Removal of the pharyngeal muscles will expose the large frontal ganglion lying on the pharynx near the anterior end of the "pump." The lateral branches going back to the brain and the recurrent nerve with its triangular ganglion can also be made out. Note that the frontal ganglion is much larger than in the imago, and that the recurrent nerve keeps on the œsophagus instead of, as in the imago, dipping over to the left side.

Remove the brain, noting the lateral commissures running down on each side of the œsophagus and grooving the sides of the pharynx.

The Tentorium. The removal of the pharyngeal muscles exposes the anterior part of the tentorium which at first appears to be very different from that in the adult. Note the anterior processes extending on each side, the apex of each fused with the head at the side of the socket which receives the dorsal articulatory process of the mandible, i.e. just anterior to the antennal socket. Trace these branches inwards and note the broad middle piece formed like a yoke and fitting over the pharynx. On each side of the œsophagus behind this, note a fine transparent, almost invisible, structure as shown in Fig. 38. This is attached to the yoke at each side by a fine connective, probably broken in removing the muscles. In the gular region it is attached on each side by a ventral process, and it is attached lightly to the epicranial plates by two dorsal processes. A dark-coloured tracheal tube runs upwards immediately behind these dorsal arms, and similarly a tracheal tube runs back, just above the posterior processes. These latter carry the "bridge" which, as in the imago, holds down the subœsophageal ganglia.

The Mouth and Sucking Apparatus. Just in front of the anterior processes of the tentorium and in the extreme angles of the frons (in front of the mandibular articulation and behind the corner of the labrum) is a small dark triangular sclerite (*TS*, Figs. 38 and 39), its outer and anterior angle lying in a white membrane. Carefully remove the labrum, which will come away so as to leave a chitinous edge as the anterior margin of the head. This exposes the labium. Note that the chitinous edge fits over a chitinous ridge across the

floor of the mouth, the two together constituting the "mouth-lock." Beneath the edge of the roof of the mouth and just behind the chitinous ridge across the floor, note a transverse groove (*tr. g.*, Fig. 39). Trace this groove out to one side and note that it comes to an end beneath the triangular sclerite already mentioned.

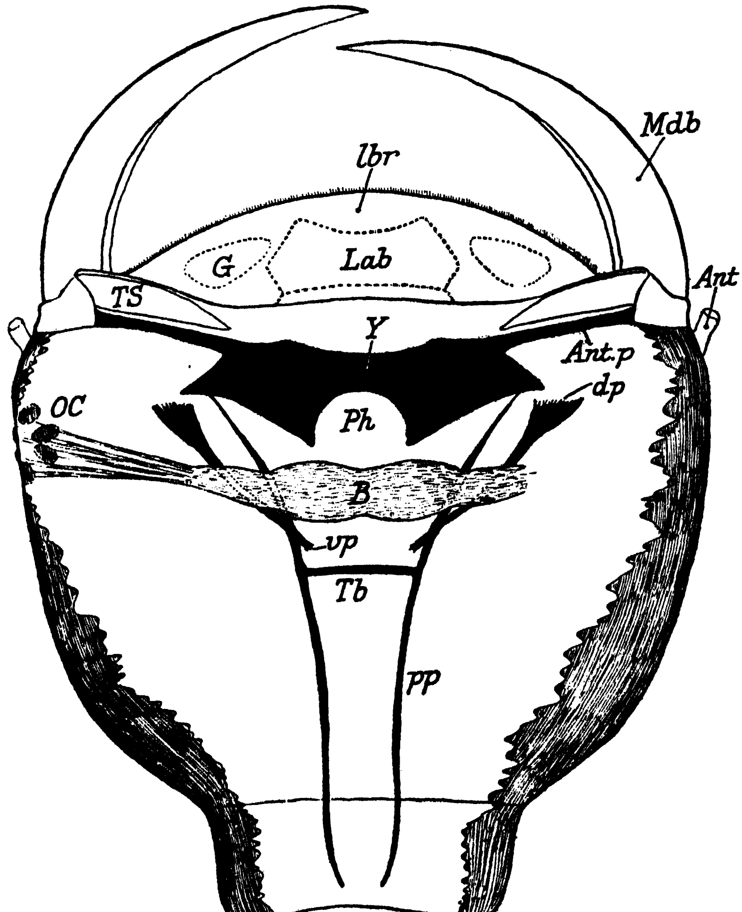

FIG. 38.—Dytiscus larva. Dorsal view of head, with frontal and epicranial plates cut out, to show the tentorium (in black).

Y = the yoke-like main structure; *Ant.p* = the anterior processes; *dp* and *vp* = the dorsal and ventral processes and *pp* = the posterior processes; *Tb* = the tentorial bridge; *Ant* = base of antenna; *B* = the brain with optic nerves running out at each side to *OC*, the ocelli; *Lab* = the labium, dotted in to show its position below the labrum; *lbr* = the labrum, on the under side of which are, *G*, two patches of gustatory cells; *Mdb* = the mandibles; *Ph* = the arch through which the pharynx passes backwards; *TS* = the triangular sclerite.

Remove this sclerite and note that the posterior opening of the mandibular tube lies immediately beneath it when the jaw is almost closed across the front of the head. When, therefore, the jaws are thus closed and the mouth-lock is closed, the only communication with the mouth is through the tubes in the jaws,

and, when the sucking-pump is at work, fluids are sucked in through these tubes (see Fig. 39).

The Alimentary Canal. The œsophagus is very short, extending only to the anterior edge of the prothorax where it ends abruptly in a ring-like thickening, all that represents the proventriculus of the imago. The mid-gut is a straight wide tube reaching to about the 5th abdominal

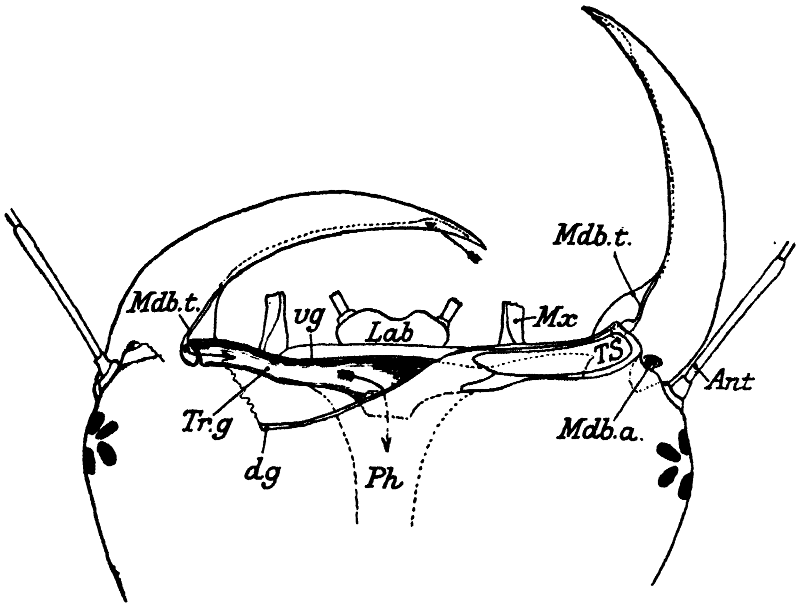

FIG. 39.—Dytiscus larva. Dorsal view of part of head to show the "sucking-tube" mouth.

Ant. = base of antenna; Labrum removed exposes Labium (*Lab*) and maxillæ (*Mx*), which have been cut off. *Mdb.a* = the boss on the base of the mandible which fits into a socket on the head and forms the dorsal articulation; *Mdb.t* = mandibular sucking tube; *Ph* = the pharynx, dotted in; *Tr.g* = the transverse groove which opens medianly into the pharynx and communicates at each end with the mandibular sucking tube; *TS* = the triangular sclerite; *dg* and *vg* are the dorsal and ventral ridge and groove which together form the mouth-lock, the left ant. part of the head having been partly cut away and partly turned back to expose the transverse groove and the ridges and groove of the mouth-lock.

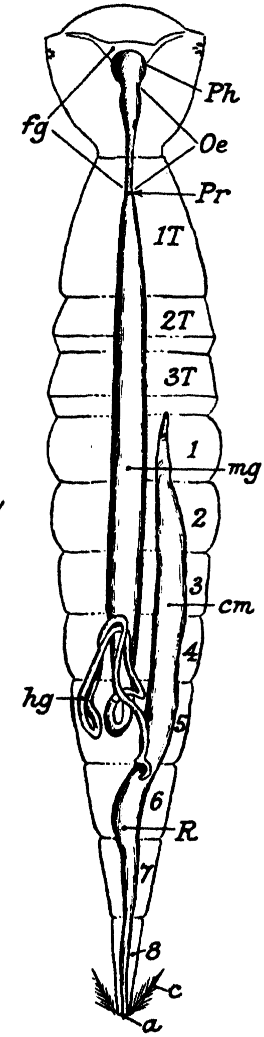

FIG. 40.—Dytiscus larva, to show the alimentary canal.

a = anus; *c* = cercus; *fg*, *mg*, and *hg* = fore-, mid- and hind-guts; *cm* = cœcum of hind-gut; *Oe* = oesophagus; *Ph* = pharynx (sucking pump); *Pr* = constriction where fore- and mid-gut join and where the proventriculus develops in the imago; *R* = rectum; 1*T* to 3*T* = thoracic segments; 1-8 = abdominal segments.

segment where it turns sharply upwards and forward and opens into the small intestine.

Open the mid-gut and note the annular glandular rings representing the short cæca of the imago. The small intestine, about which are coiled the malpighian tubules, bends about in segments four and five and ends in segment six, where it enters the large intestine, which runs straight back to the anus at the posterior end of the body, and forward as the cœcum to the anterior end of the abdomen (see Figs. 40 and 41).

The Central Nervous System. Carefully remove the alimentary canal and expose the central nerve-chord. From the subœsophageal ganglia, long commissures run to the prothoracic ganglia in the middle of the prothorax. The nerve-chord then runs beneath some of the series of segmental muscles, some transverse and some oblique. The mesothoracic ganglia are in the middle of the mesothorax and the metathoracic and 1st abdominal in the metathorax. The 2nd abdominal ganglia lie close behind the 1st but concealed beneath some

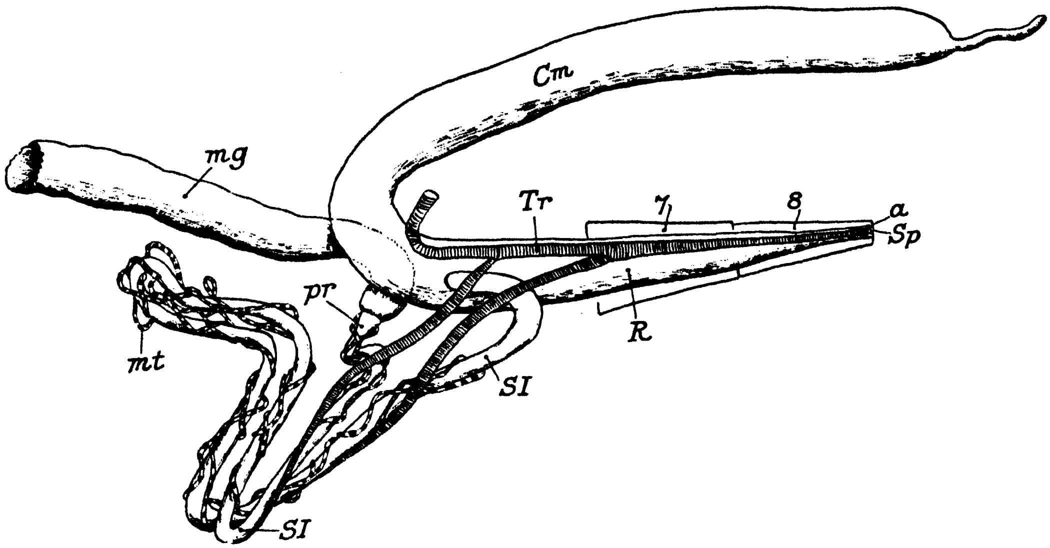

FIG. 41.—Dytiscus larva. Posterior half of alimentary canal to show connection of mid- and hind-guts and the entrance of the small intestine into rectum.

a = anus; *Cm* = cœcum; *mg* = mid-gut; *mt* = malpighian tubules; *pr* = pyloric ring, the connection of mid- and hind-guts and where the malpighian tubules enter the gut; *SI* = small intestine; *R* = rectum; *Sp* = spiracle; *Tr* = trachea.

of the transverse muscle-fibres, and the remaining six pairs also lie in the metathorax and 1st abdominal segments, the 7th and 8th being almost indistinguishable.

The Reproductive System. Consists of a small capsule, in the 3rd or 4th abdominal segment, on each side of the body, close beside the lateral tracheal trunk and closely associated with a small branch-trachea which comes off the main trunk in the 4th segment. The genital duct runs back, and, about the 6th segment, enters a complex of tubes which thins out posteriorly and cannot be traced to a definite end.

Note that there is no external genital armature, a structure always absent from larvæ but present in nymphs.

II. *THE MOUTH-PARTS OF INSECTS*

(1) Mouth-parts of Thysanura

Machilis. Prepare, stain and mount the mouth-parts and note the "horned" mandibles. Note also the large hypopharynx, and, on each side, a structure which is regarded by some as a true appendage, homologous with a leg or antenna (e.g. Carpenter) and by others as a lateral portion of the hypopharynx, a mere paragnath (e.g. Crampton).

(2) Mouth-parts of Orthoptera

Examine a series of slides [1] of the mouth-parts of representatives of different families of the Order, e.g. Forficulidæ, Blattidæ, Acridiidæ, Gryllidæ, Mantidæ. Note that the type is "mandibulate," as is evidenced by the nature of the mandibles and the maxillæ. (*N.B.*—Mandibles alone do not determine whether mouth-parts are mandibulate or haustellate.)

Note that, although some of the families are entirely and others partly vegetarian and one (Mantidæ) carnivorous, the mouth-parts are very similar throughout.

Having carefully compared the mouth-parts of a number of the types, select a slide and make out definitely the sclerites of the maxilla and labium and draw.

Note that nymphs and adults of Orthoptera live under similar conditions and have similar mouth-parts.

(3) Mouth-parts of Odonata

Compare those of a nymph and an imago, removing them from both and making permanent mounts. Draw and label the parts.

Note the peculiar form of labium in the imago, in which the ligula and paraglossæ are absent and the palpi (2-segmented) are expanded and function as "nippers" for seizing and holding the prey, although, once the prey is captured, the legs are also brought into action, as the insect usually feeds while upon the wing.

Note the labium of the nymph, known as the "mask," capable of being projected forwards and withdrawn under the head. The form is much the same as in the adult, but the mask continues to hold the prey after capture as the legs do not assist.

[1] In the time allotted for the practical work, it is impossible for the student to prepare more than one or two at most of the slides in this series. It is therefore necessary to have a supply, and it will be found that many other slides are required in order to carry out the course according to the time schedule.

The adult lives in the air and the nymph in the water, and the mouth-parts of each are adapted to their special requirements.

(4) Mouth-parts of Ephemeroptera

(Worked either from slides or specimens.)

The mouth-parts of the nymph of the May Fly (*Ephemera vulgata*).

Note the "horned" mandibles and the pair of processes on the head immediately above the labrum.

These nymphs live in the gravel in streams, and the processes are used for digging a passage through the stones.

Note that the hypopharynx is well developed and possesses, on each side, a lobe which may be a maxillula.

(5) Mouth-parts of Rhynchota (Hemiptera)

(Worked from slides or specimens, preferably a Cicada, but Nepa or Notonecta is satisfactory.)

The mouth-parts of the bugs show little variation from the type except in length, and when the mouth-parts are lengthened the labium (Rostrum) becomes segmented.

It is possible that in some, perhaps many, cases the labium acts as a piercing organ, but it is certain that in a number it does not.

It is grooved along its upper side and forms a pouch for the stylets, which consist of a pair of mandibles, independent of one another, and a pair of maxillæ, closely applied to one another and held together so firmly that it is often difficult to separate them.

Between the two maxillæ the saliva passes down into the food material, and, according to most authors, the dissolved food passes up between them also.

The hypopharynx is minute, merely forming a valve over the orifice of the salivary duct.

The labrum is short, only covering the basal part of the labial groove.

The base of the maxilla is a large plate to which the stylet is but lightly joined. The base of the mandible is flattened, as is also the mandibular ligament which is fused firmly to it, and this ligament lies far back in the head beneath the elongated tentorium.

Examine the mouth-parts of the Cicada (Nepa or Notonecta), first in their natural positions and then as separate pieces, obtained by boiling the head in potash and carefully dissecting out. Make sure that the bases of the stylets are not left in the head.

(6) Mouth-parts of Neuroptera

The mouth-parts of larvæ of Myrmeleonid, "Ascalaphid, Chrysopid or Hemerobiid," worked from slides or specimens.

In connection with special feeding habits, the sucking of the blood of their prey, the mouth-parts of certain Neuropterous larvæ are modified from the normal mandibulate type.

Note the peculiar form of the maxilla which closely resembles the mandible.

The mandible and maxilla on each side can be brought together so as to form a tube. These tubes are driven into the prey.

Draw a set of mouth-parts, labelling them.

(7) Mouth-parts of Coleoptera

(*a*) Prepare in the usual way and mount the mouth-parts of a Scarabæid beetle (e.g. Melolontha or Rhizotrogus) as an example of the typical "mandibulate" mouth-parts of Coleoptera.

(*b*) Prepare in the usual way and mount the mouth-parts of a larva of a Scarabæid beetle (e.g. Geotrupes, Oryctes, etc.). The points of special note are the horny hypopharynx, lacking bilateral symmetry, and the two unequal sclerites attached, one on each side, to this median plate. These are regarded as metamorphosed maxillulæ by some (*vide* G. H. Carpenter and MacDowell: "The mouth-parts of some beetle larvæ (Dascillidæ and Scarabæidæ) with especial reference to the Maxillulæ and Hypopharynx." *Q.J.M.S.*, 57, pt. 4, 1912, pp. 373–96, 3 plates).

(*c*) Examine the mandibles of a Scarabæid beetle, e.g., Copris or an allied genus, to see the division into several sclerites which, by some authors, have been regarded as representing cardo, stipes, etc., but by others are regarded as secondary divisions.

Note the gnathobases or "mola processes."

(*d*) Prepare and mount the mouth-parts of a larva of Agriotes or other Elaterid beetle. Note the absence of labrum. Besides the usual mandibles, maxillæ and labium, there is a distinct hypopharynx in the floor of the mouth and, overlying this, a pair of lobes which are either maxillulæ or paragnaths.

(*e*) Prepare and mount the mouth-parts of a Weevil (e.g. *Hylobius abietis*, *Otiorrhynchus picipes*, etc., etc.).

Note the short, more or less rigid palpi of the maxilla and labium. (*N.B.*—One of the characteristics of most of the series Rhyncophora is the rigidity of these palpi.)

Note also the hairy hypopharynx on the floor of the labium.

(*f*) Prepare and mount the mouth-parts (or examine prepared slides) of a ground-frequenting beetle such as a Carabid or Cicindelid and of a flower-visiting species such as the Cerambycid (*Agapanthia*), or certain Telephorids, etc.

Note that, although both beetles have "mandibulate" mouth-parts, the anthophilous one has them more hairy, i.e. specially adapted for pollen- or nectar-gathering.

(*g*) Examine slides of the mouth-parts of one or both the Meloid beetles, Nemognatha and Zonitodema.

In these, the galeæ of the maxillæ are lengthened out and somewhat flexible and together, the galeæ form a sucking-tube, as in Lepidoptera, but differing

therefrom in that, in the beetle, the tube is not capable of being curled up under the head.

(*h*) Examine a slide showing the mandibles of the larva of the "Glow-worm" (*Lampyris noctiluca*), family Lampyridæ.

Note that through the length of each mandible runs a tube (through one of which a bristle should be pushed). These tubes are developed in connection with the feeding habits of the larvæ. The food consists of snails and an anæsthetizing or paralysing fluid is pumped into the prey through the mandibular tubes. The fluid is probably also digestive.

(For a description of the mouth-parts, *vide* K. Haddon: "On the method of feeding and the mouth-parts of the larva of the Glow-worm (*Lampyris noctiluca*)," *Proc. Zool. Soc.*, 1915.)

(*i*) Examine a slide showing the larva of the "Whirligig" beetle (Gyrinus).

Note that here also the mandibles have tubes running through them. Little is known as to the habits of these larvæ which spend a large part of their time in the mud at the bottom of the pond or amongst the vegetation in deep water; but, presumably, the tubes are for sucking the blood of the prey and probably also for injecting digestive fluids into the prey.

(*j*) Prepare and mount the mouth-parts of a Dytiscid larva.

According to species, the mandibles will show a deep groove along the inner edge or a fine tube running from just beneath the pointed apex to the base where it opens dorsally. The Dytiscid larva is carnivorous and sucks the blood of its prey through the grooves or tubes in the mandibles, and, at intervals, ejects a digestive fluid through the same channels.

(8) **Mouth-parts of Lepidoptera**

Remove the head of a butterfly (e.g. Garden White or Tortoiseshell, etc.) or of a Moth (e.g. Yellow Underwing (*Triphæna pronuba*, etc.)), boil in potash and mount so as to show the mouth-parts complete. (*N.B.*—The maxillæ are the main part and the cardo and stipes lie within the head.)

Having mounted the mouth-parts, compare with a slide showing the mouth-parts of a Micropterygid Moth, a primitive family with typical "mandibulate" mouth-parts.

In some families of Moths, e.g. Lasiocampidæ, the maxillæ, which in others form the proboscis, are obsolete.

(9) **Mouth-parts of Hymenoptera**

(*a*) **Vespa** (Wasp or Hornet). Examine slides or prepare the mouth-parts. These consist of a pair of large mandibles, a pair of maxillæ and the labium. The mandibles require no comment.

Labium. Note the bifurcate character of the "ligula," i.e. the two laciniæ, with the curious hard chitinous discs at the apex of each fork. The upper surface is covered with strong curved spines with spathulate apices. On each side of the ligula is a paraglossa (galea), bearing at its apex a hard chitinous disc, similar

to those of the ligula. At the bases of the paraglossæ, note the chitinous strut between them and the framework at the base of the ligula, and, in the median line of this region, note the small hairy lobe which appears to carry gustatory organs. Some distance behind this is a large broad lobe which is probably the hypopharynx.

The ligula and paraglossæ are borne upon a large basal mentum (fused stipites), which bears on each side a 4-segmented palpus, the segments of which are more or less alike in size. There is no submentum, the cardines having disappeared, although existing in most other hymenoptera.

Maxilla. The apical piece of the maxilla is a bilobed galea, the larger part of which may be called the subgalea bearing the smaller galea. (See note as to the use of the term "subgalea" on p. 8.) At the extreme base of the subgalea and on its inner edge is a small lacinia.

The stipes is divided longitudinally, one part being the "palpiger" bearing the 6-segmented palp.

Below the stipes is a small cardo.

The wasp mouth-parts are slightly modified from the typical mandibulate type and are specialized for scraping (as is evidenced by the nature of the labial hairs) and for licking, the labium being somewhat of the form of a painter's brush.

(*b*) **Bombus** (Humble-Bee) **or Apis** (Hive Bee).

The mandibles are of the same character as those of the wasp, but smaller.

The labium consists of a long ligula, the upper surface of which is transversely striated, each stria bearing a series of long downwardly-projecting, pointed hairs. At the apex of the ligula is a small spoon-shaped piece (not found in the male), covered with hairs and arising out of a tuft of hairs. Immediately behind this is a more or less square plate (before the transverse striæ begin), and on this, chiefly on the under side, are several small pits bearing sensory hairs (gustatory organs).

The upper side, or front face, of the ligula curls round the sides and the true, under side, has no transverse striæ nor hairs, but is divided in the median line by a narrow groove which runs from the apex, immediately behind the "spoon," to near the base. On the upper side and in the basal region is another short groove leading into the mouth. A pair of paraglossæ embrace the base of the ligula in the region of the dorsal groove, and these are bilobed with a small dorsal and a large ventral lobe to each paraglossa.

The ligula and paraglossæ are borne upon a long narrow mentum bearing, at the apex on each side, a 4-segmented palp, as in the wasp; but the palpi have the two basal segments very long, reaching almost to the apex of the ligula, and grooved on the inner face so that the two together can form a trough beneath the ligula and tend to close in above it.

The maxilla. The long pointed blade-like part is the galea, and the small

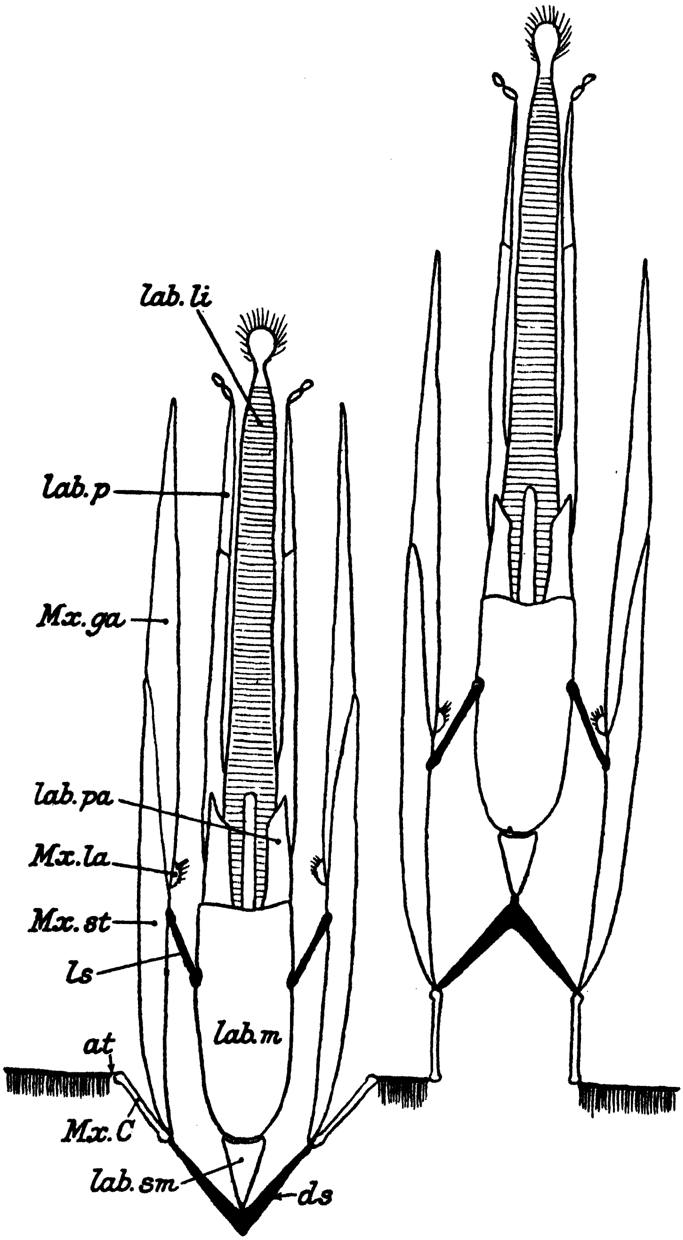

FIG. 42.—Diagrammatic illustration of the movements of the mouth-parts of a bee.

at = attachment of mouth-parts to head; *ds* = double strut (known as the "lorum"); *ls* = lateral strut; *lab.li* = ligula; *lab.pa* = paraglossa; *lab.m* = mentum; *lab.p* = labial palp; *lab.sm* = submentum; *Mx.C* = cardo of maxilla; *Mx.ga* = galea; *Mx.la* = lacinia; *Mx.st* = stipes.

lacinia, bearing a few strong hairs, can be seen at the extreme base of the galea on its inner edge. The galea and lacinia are borne upon a long narrow stipes which bears a minute 2-segmented palp and the stipes is borne by a long narrow cardo.

The Working of the Mouth-parts (e.g. in Bombus). Examine the mouth-parts *in situ*; move them about and see how they work, with the assistance of the following notes:

Between the base of the submentum and the cardo-stipital joint of the maxilla is a short strut, and about half-way up the maxillary stipes, on its inner edge and just below the insertion of the lacinia, is a similar strut, running across to about the middle of the side of the mentum. The lateral struts serve to steady the maxillæ if they are spread outwards or to steady the labium when it is projected forwards, but the posterior struts, frequently united into a V-shaped structure and known as the "lorum," are those upon which the whole labium moves backwards and forwards.

The maxillary cardines rotate upon their basal attachments in such a way that the stipital joints

are anterior when all the parts are protruded and posterior when the mouth-parts are withdrawn, in which latter condition the basal ends of the cardines lie against the sides of the stipites (see Fig. 42).

Evolution of the Maxilla. In some of the forms with a ligula of the "painter's brush" type the maxillæ are short, the stipes bearing the galea and lacinia side by side upon a transverse apex, e.g. in Cephid Sawfly.

The changes which take place in the process of evolution are:

(1) The lengthening of the galea and reduction in size of the lacinia.

(2) A change in form of the stipes, the galea- and lacinia-bases, as it were, slipping down its side so that the apex of the stipes becomes oblique.

(3) The diminution in size and in the number of the segments of the maxillary palpi.

Trace this series in such types as the following:

Cephid and Tenthredinid Sawfly, Vespa, Andrena, Melecta, Nomada, Panurgus, Halictus, Macropis, Dasypoda, Bombus and Apis.

Evolution of the Ligula in Bees. Starting from forms with the "paint brush" type, a series can be made out in which the ligula gradually lengthens, and this series passes from the most primitive bees through intermediate types to the highest forms. Changes in the mentum, paraglossæ and labial palpi accompany the changes in the ligula, and the following series will illustrate some of these:

Colletes, Prosopis, Sphecodes, Macropis, Andrena, Cilissa, Halictus, Dasypoda, Nomada, Panurgus, Melecta, Eucera, Coptorthosoma, Bombus, Apis.

(10) **Mouth-parts of Diptera**

The specialization of mouth-parts of the Diptera has been in two directions: one for piercing and sucking and the other for sucking surface fluids.

(*a*) **Mouth-parts for piercing and sucking.** In Tabanids and Culicids, the mouth-parts are all lengthened, the labrum, mandibles, maxillæ and hypopharynx being long and narrow stylets while the labium is grooved in its upper surface and acts as a sheath to hold the mandibles, maxillæ and hypopharynx, the labrum covering the groove above. In this type the labrum apparently acts as a piercing organ. Specialization of this type has been in the loss of some of the stylets, and apparently the labium has become the piercing organ in some cases, e.g. Glossina. In other cases, e.g. Asilidæ, the hypopharynx is apparently the piercer. Labial palpi are absent in the Diptera, except in a few very primitive forms, e.g. some Blepharoceridæ, but maxillary palpi are often well developed. In the Culicidæ, the maxillary palpi are long in the male, e.g. Culex and Anopheles, and may be short (Culex) or long (Anopheles) in the female. Culicid males have no stylets.

Examine specimens or slides of male and female Anopheles and Culex and make out these points.

In the Tabanid, both male and female have the full complement of mouth-parts.

(*b*) **Mouth-parts for sucking surface fluids.** The labella, or lobes, at the apex of the labium, are more or less simple in the piercing-and-sucking flies, but they become elaborate in the surface-suckers and the elaboration of the labella is, in most forms, associated with a loss of mandibular and maxillary stylets, e.g. Muscidæ.

It must not, however, be imagined that the evolution of mouth-parts into the *a* and *b* groups has run parallel with the evolution of the Diptera because examples of both types may occur in one family. In the Muscidæ, Musca shows the most highly developed labella and extreme specialization for sucking surface fluids while Stomoxys and Glossina have poorly-developed labella and their mouth-parts are for piercing and sucking. Stages in the elaboration of the labella may be seen in Tabanidæ, Empidæ, Syrphidæ and Muscidæ.

For loss of mouth-parts see Stomoxys, Glossina, etc., in the Muscidæ (forms with a labial piercer); and Dysmachus, Philonicus, etc., in the Asilidæ (forms with an hypopharyngeal piercer).

W. Weché's theory as to the existence of labial palpi in Diptera.

Paper 1. "Undescribed palpi on the Proboscis of some Dipterous Flies with remarks on the mouth-parts in several families," *Journ. Roy. Microscopical Soc.*, 1902, pp. 412–16.

2. "The Labial" and "Maxillary Palpi in Diptera," *Trans. Linn. Soc.* (ser. 2), IX (Zoology), 1903, pp. 219–30.

(1) In the reduction of mouth-parts in Diptera, the mandibles first disappear and chitinous rods (which are usually absent in flies with complete mouth-parts) appear in the dorsal side of the labium, bordering the lips of the groove. The pseudo-tracheæ are also more distinct; e.g. Empidæ and Syrphidæ (and see also certain Tabanids with chitinous rods in addition to the full complement of mouth-parts). Packard and others have regarded these chitinous rods as submerged mandibles.

(2) Where both mandibles and maxillæ have disappeared, there is the same chitinous-rod structure in the labium, and the basal parts of the maxillæ can be found in the base of the labium, acting as levers for working the labrum. See Calliphora and Stomoxys (Muscidæ).

(3) In the Syrphidæ, the maxillæ are composed of cardo, stipes, palpiger and galea, the lacinia having gone. Well-marked ridges half-way down the maxilla indicate the division between cardo and stipes. In these forms "palpi" are made out, attached to the cardo and stipes, whereas the palpi usually recognized as those of the maxilla, e.g. in Muscids, are attached to the membrane of the labium, some distance from the lever working the labrum.

In some families, e.g. Sarcophagidæ, Anthomyidæ, Sepsidæ, Opomyzidæ, Borboridæ, etc., minute structures project from the apices of the levers. These,

according to Weché, are the galeæ. See Peterson, A., "The Head-capsule and Mouth-parts of Diptera," *Illinois Biological Monographs*, III, 1916, 112 pp.

In Dilophus (Bibionidæ) the single pair of palpi emerge low down on the labium; a point which Weché urges as indicating that they are labial palpi. See, however, a paper by Tillyard, R. J., "Australian Blepharoceridæ," *Australian Zoologist*, II, 1922.

III. *WING-COUPLING APPARATUS*

THE most primitive form of wing-coupling apparatus consists of: (1) A Jugum (or Jugal lobe) projecting backward from the anal area of the fore-wing and bearing a number of sensory bristles; and (2) a Humeral lobe projecting forward from the humeral angle of the hind-wing and bearing a number of sensory bristles, the "Frenulum." The fore-wing bristles and the frenulum conveyed sensations as to the movements of the other wing to the nerve-centres of their own wing segment.

In the Mecoptera, e.g. Panorpa (Scorpion fly), this primitive arrangement exists.

In the Neuroptera, e.g. Hemerobiidæ, the fore-wing bristles have disappeared.

In the Trichoptera the frenulum and humeral lobe are gone and also the jugal bristles, but the jugum persists and, in flight, overlaps the hind-wing.

In the Lepidoptera the frenulum, for the most part, exists. In the lowest Lepidoptera, e.g. Micropterygidæ, the frenulum consists of only three bristles and the jugum is apparently turned back against the base of the fore-wing.

Whether it acts as a catch or "retinaculum" for the frenulum is not clear and requires investigation.

In the Hepialidæ the frenulum has gone, as has also the humeral lobe. The jugum projects backwards and downwards and apparently catches beneath the anterior edge of the hind-wing while, farther away from the base, the hind-wing underlies the posterior edge of the fore-wing.

In the higher Lepidoptera, the frenulum has lengthened considerably and consists of a tuft of two, three or more hairs in the female and a fused group of hairs in the male. The jugum has disappeared and a new apparatus has appeared on the under side of the fore-wing. This differs, according to sex, being in the female a small tuft of hairs projecting forwards from the "cubitus" vein, towards the posterior margin of the wing, and in the male a chitinous loop projecting from the "subcostal" or from the "radial" vein towards the anterior margin of the wing.

In certain families amongst the higher Moths (e.g. Lasiocampidæ, etc.) and in all the butterflies the frenulum has disappeared, and the only part of the apparatus persisting is the humeral lobe which, in the butterflies, is enlarged.

Wing-connection in all forms of Lepidoptera without a frenulum is maintained by overlap ("amplexiform" type of Tillyard).

In Hymenoptera, wing-connection is maintained by a series of hooks projecting forward from the posterior margin of the hind-wing and engaging with the downturned posterior margin of the fore-wing.

In Rhynchota-Homoptera (e.g. Cicada) wing-connection is maintained by the up-turned margin of one wing engaging with the down-turned margin of the other.

Perhaps the wing-coupling apparatus seen in Hymenoptera and Homoptera may be regarded as an advance on the ordinary Amplexiform type.

Vide Tillyard, R. J., "The Panorpoid Complex," *Proc. Linn. Soc.*, N.S.W., XLIII, 1918.

IV. A STUDY OF LEGS

1. The leg of the cockroach will have made you familiar with the parts, coxa, trochanter, femur, tibia and tarsus. Of these, coxa, femur and tibia are of one segment, while the trochanter is usually so. In some cases, however, the trochanter is 2-segmented and in the Hymenoptera Parasitica almost all the species are characterized by having a 2-segmented trochanter.

Examine the leg of one of this group, e.g. an Ichneumonid, and note this fact.

2. Mount one of the legs, say a posterior one, of each of the following beetles: (*a*) a Coccinellid (Polymorpha); (*b*) a Cerambycid (Phytophaga); and (*c*) a Curculionid (Rhynchota) and examine the tarsus. Note that (*a*) has four segments, the 3rd being so small and so associated with the 2nd that the Coccinellidæ and certain related forms were at one time grouped together under the name "Trimera," in the belief that only three tarsal segments existed in them; (*b*) has five segments, the 4th being minute and the Cerambycids and related families were at one time placed in a group, the "Tetramera," from the apparently 4-segmented tarsi; (*c*) has 5-segmented tarsi, as in (*b*).

3. Mount one of the anterior legs of a male and a female Dytiscid beetle and compare the tarsi. Note the simple tarsus of the female and the padded tarsus of the male, the size of the pads depending upon the genus and species selected. The pads are of use in holding the female during copulation. In a number of insects, the tarsi of the males are broader and have larger ventral pads of hairs than those of the females.

4. Mount one of the legs of a Muscid fly and examine the apex of the tarsus, noting the pads or pulvilli between the claws. A pair of these exist in many insects, and between them or instead of them there is often a structure, the empodium, which may be pad-like, "pulvilliform," or a mere bristle, e.g. Asilus. In the Muscid, the empodium is absent.

5. Tarsal Claws. Usually two in number, one in a number of insects (e.g. the majority of beetle larvæ) and three in "Triungulins," although the median one is large and the laterals are very small. They vary in form in different insects and often in the two sexes, which can frequently be distinguished on this character.

Examine the claws of any of the insects already mentioned and note that they are simple, except possibly in the Dytiscid where, depending on the kind selected, sexual differences may exist. Those of an Odynerus "wasp" are toothed, while those of a Melöid (Cantharid) beetle are either split each into two, one above the other, or toothed. Those of a Cistid beetle are pectinate.

6. Examine the anterior leg of Apis, Bombus, Vespa or other Hymenopterous insect and note the "antenna cleaner," a structure belonging to both tibia and tarsus. The former's contribution is a modified spur or spine beneath the apex, which closes over a hollowed-out region in the base of the tarsus. The antenna, drawn through the circle formed by these two parts, is cleaned from particles of dirt which may be adhering to it. (*N.B.*—In many beetles there is a cut-out region in the base of the tarsus which is lined with stiff bristles and this probably also acts as an antenna-cleaner.)

7. The Pollen-collecting Apparatus of a Worker Bee of Bombus or Apis. First examine the body of the bee and note the thick hairy covering, especially upon the under side. Remove a few hairs, mount and examine them under the microscope and note that they are branched or "compound" hairs, the branching helping in the holding of the pollen grains.

Examine the hind-legs *in situ* and note that the outer face of the tibia is hollowed out, the sides of the more or less triangular hollow being fringed with long hairs. This is known as the "corbicula" or "pollen-basket," and its open posterior end possesses a "comb" of short stiff hairs.

Next, note the 5-segmented tarsus, the basal segment of which, usually called the "metatarsus," is much larger than the others. Note that, at its base, it bears a small projection, the "auricle," strongly fringed with hairs, which, by movement of the metatarsal joint, can be brought to or away from the broad apex of the corbicula.

Note the inner face of the metatarsus. It is covered with stiff irregularly-arranged hairs in Bombus and with similar hairs arranged in about ten rows in Apis, the hairs all pointing towards the apex of the leg.

The working of the parts. The parts described are the essential pollen-collecting apparatus and work as follows:

The bee visits flowers to obtain nectar, brushes against the stamens and the pollen gets caught up amongst the compound hairs. At short intervals the bee rests from nectar-gathering and brushes itself with its legs, passing the pollen back beneath the body to the hind-legs, the pollen, or the front-legs, having previously been moistened from the bee's mouth. The metatarsal brushes receive the sticky pollen and the two hind-legs are then rubbed together, the comb at the opening of the corbicula gathering the pollen off the metatarsal brushes of the other leg.

By working the metatarsus backwards and forwards the auricle then pushes up the mass into the corbicula. The first mass pushed into the basket remains just inside until another mass is pushed in and thus moves the first mass farther up. A third mass pushes up the second and so on until the basket is full.

V. THE RESPIRATORY SYSTEM AND ADAPTATIONS OF AQUATIC INSECTS

The Respiratory System

The Tracheal System, the Spiracle and Spiracular-control Apparatus.

Take a caterpillar, say, of a Noctuid Moth, preferably not more than about one inch long, because it is easier to work with; push one point of a fine pair of scissors into the anus and cut along the median ventral line to the head and then back along the median dorsal line to the anus. Boil one half in strong potash until all soft parts have dissolved and then wash in water. It will be found that the lateral tracheal trunk and its main branches are left attached by the spiracular branches to the skin.

Note the elaborate branching system and then remove and examine part of the main trunk to see the tænidia, the thread-like chitinous thickenings running spirally on the inner wall of the tube.

Lay the skin upon a slide, outer side uppermost, and examine a spiracle under the microscope. Note the oval "peritreme" and that the opening is closed by two lips which meet in a vertical line. The lips appear to be marked transversely with parallel lines, but further examination shows that they are composed of numerous finely-branched processes, the branches holding the processes together. The lips meet at an angle, suggesting that they would open easily inwards but not outwards.

Reverse the skin and note that behind each spiracle is a tuft of tracheæ which unite to form a short tube, the "atrium" or "vestibule," just inside the spiracle.

Now take the other half of the caterpillar and carefully remove the contents without disturbing the tracheal tufts over the spiracles or the skin muscles in their neighbourhood.

Very carefully remove a tracheal tuft and expose the atrium, noting that, when looking into the cut end, the spiracle itself is not visible because one side of the atrium is squeezed towards the other just where it joins the back of the spiracle. Examination with a needle will reveal a narrow chitinous bow round the side which is not squeezed and a chitinous lever in the wall of the squeezed side. This is the spiracular-control apparatus, and the end of the lever will be seen to be attached to two muscles, one, the thinner, running upward and opening the slit, the other, the thicker, running ventrally and closing it. Move the lever with a fine pair of forceps and see how it works.

Types of Spiracle.

(*a*) *The simple spiracle.* The simplest form is one in which the opening is surrounded by the peritreme and unprotected by lips. Such open holes occur in various insects, but, as a rule, the opening is protected as just seen, or as seen in Dytiscus.

(*b*) *The sieve-plate spiracle.* Examine the spiracle of a larva of Melolontha, Geotrupes, or other Scarabæid beetle. Note that, although the peritreme is oval, there is a solid central "bulla" broadly connected with it so that the functional part of the spiracle is somewhat kidney-shaped. Either treat the larva as the caterpillar was treated or cut out a spiracle and examine it under the microscope. By clearing away the muscular tissue and tracheæ on the under side, a large atrium

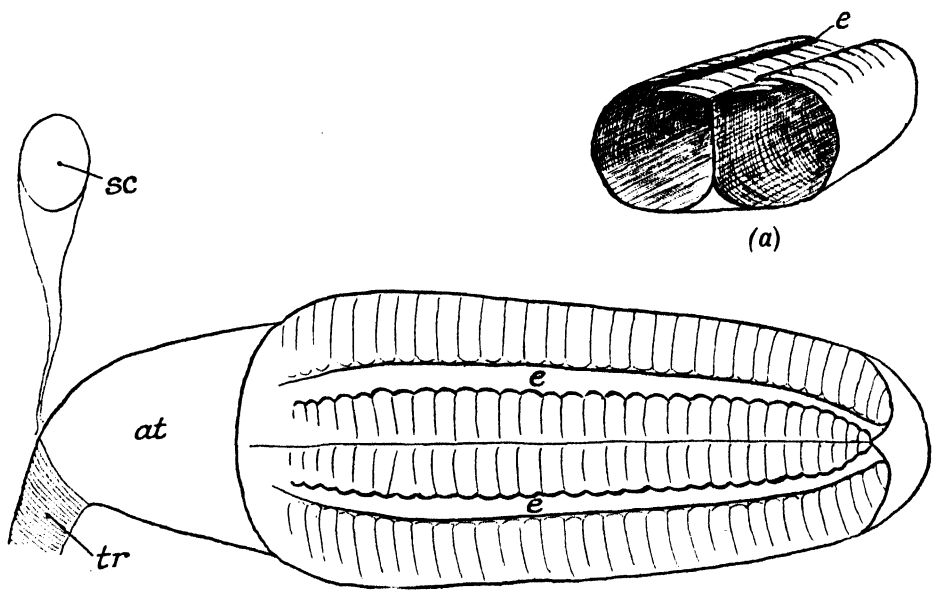

FIG. 43—Biforous spiracle, of an Elaterid larva (Agriotes sp.) looked at from above. *at* = atrium; *ee* = the long slit entrances to the spiracle (see also Fig. 43(*a*); *sc* = the scar; *tr* = the spiracular trachea. Fig. 43(*a*) shows a section through the spiracle.

will be found immediately beneath the spiracle. There is no control apparatus. Note that the inner face of the spiracle is protected by a number of branched processes or trabeculæ which spread across the face from the outer margin and that these trabeculæ lie on a membrane pierced by fine pores.

Examine this pore-bearing membrane or sieve-plate, both from the inside and the outside, and note that it is firmly attached all round and that, except through the pores, there is no opening in it.

(*N.B.*—Imms, A. D., *Textbook of Entomology*, 1926, p. 108, states that the true opening in this type of spiracle is a curved slit round the inner margin of the sieve-plate, but this is not so. If such a slit exists it is due to an accident in handling the material.)

The bulla has an internal attachment.

(*c*) *The biforous spiracle.* A type characteristic of certain beetle larvæ, e.g. many Chrysomelidæ and Curculionidæ, Lampyridæ, Dermestidæ, Byturidæ, Byrrhidæ, etc., etc., but the type varies in different families. Examine the spiracles of an Elaterid larva (e.g. Agriotes) and of a Curculionid (e.g. Hylobius abietis).

In the Elaterid, note that it appears to be double throughout its length and that it lies in a slight depression. Very careful manipulation will show that two slits exist, one along each half of the spiracle, but that, in a state of rest, the slits are closed by the overlapping of the smooth edges (see Fig. 43).

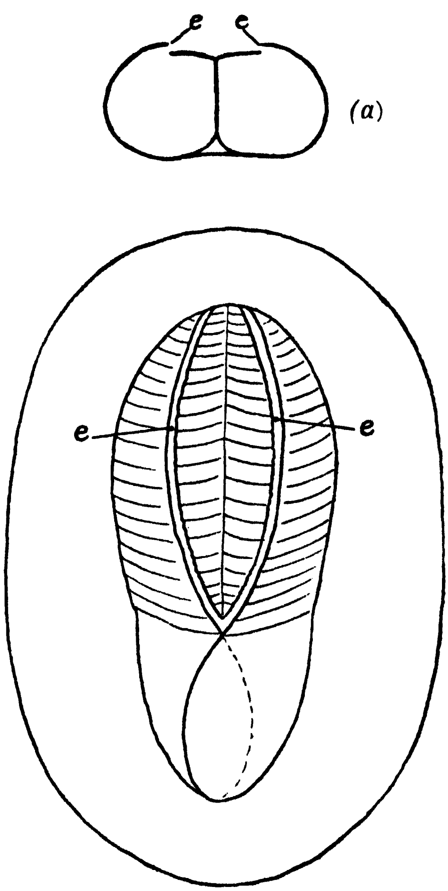

FIG. 44.—Biforous spiracle of a Weevil (*Hylobius abietis*) looked at from above.

ee = the long slit-like entrances to the spiracle (see also Fig. 44(*a*)), the transverse section.

Examine the spiracle from beneath and note that, at one end of it—that towards the head of the larva—is the atrium and the spiracular branch of the trachea. Now examine it from above and note that at the same end and above the atrium is a minute oval "scar" in the chitin of the body wall, and, if the chitin is sufficiently transparent, a fine tube will be seen descending from beneath this and coming into contact with the wall of the atrium. This is the remains of the spiracle of an earlier stage of the larva.

(It has been suggested, by way of explanation of the fact that a new spiracle arises at the moult, that this type of spiracle is too complex to allow the lining being cast out in the usual way at the time of the moult. The only comment is that apparently some forms of biforous spiracles are not so complex and are not renewed with each ecdysis, e.g. there is no scar connected with the spiracles of Hylobius.)

Now examine the spiracle of Hylobius, which is oval in shape, the long axis being vertical, and note the great differences between it and the one just examined. Here the structure is only double in its upper half. Manipulation with a needle will show that there is a long slit, of which the lips overlap in the lower half and spread wide apart in the upper half, a wedge-shaped ridge rising between them and thus making the slit into two. Here again the spiracle in a state of rest is closed. There is no controlling apparatus (see Fig. 44).

(*N.B.*—These spiracles are very nice mounted as microscope slides, but the details of structure are only to be made out in the manner indicated.)

Adaptation to an Aquatic Life

All aquatic insects are descended from forms which have become adapted to life in the water and, with very few exceptions, no insect spends the whole of its life-cycle in the water. Those which are best adapted and can breathe the dissolved air are "true aquatics," while those which require atmospheric air are "false aquatics."

(1) False Aquatics

Adult insects are probably always false aquatics.

(*a*) **A Dytiscid and an Hydrophilid Beetle.** Note the difference in general form, the Dytiscid being a swimmer, the Hydrophilid, although often a good swimmer, is largely a creeper and, so far as British genera are concerned, the majority are poor swimmers.[1]

Compare the antennæ: in the Hydrophilid it is clubbed, for breaking the surface film when the insect renews its air supply, its thoracic spiracles and its ventral air-reservoir being, by this means, brought into contact with the air. This is the only function of the antenna beneath the water, the maxillary palp acting as the antenna and being, therefore, lengthened out. Hence the old name of the group, the "Palpicornia." The antenna functions normally when the insect is out of the water.

The Dytiscid comes to the surface "tail" first to renew its air supply and its only air-reservoir is sub-elytral.[2] Thus, the most important spiracles of the Dytiscid are the last (8th) pair, which are specially large.

(*b*) Most aquatic larvæ of the false aquatic type are "metapneustic," i.e. have only the last pair of abdominal spiracles open, or "amphipneustic," i.e. have the prothoracic and the last abdominal spiracles open, all the others being closed.

Examine a larva of a Dytiscid or a Hydrophilid Beetle or of a Gnat (Culex or Anopheles) as metapneustic types and a larva of the fly Eristalis, the "Rat-tailed maggot," as an amphipneustic type.

(*c*) A special type of false aquatic is that seen in the larva of the aquatic Chrysomelid beetles of the genus, Donacia. The larva is metapneustic, but the spiracles open in a pair of pointed processes on the 8th abdominal segment. The larva does not come to the surface for its air supply but lives in the mud under the water and feeds upon the roots of water-lilies and other aquatic plants. It obtains its air by piercing the tissues of the plant by means of the pointed processes and thus brings its tracheal system into communication with the intercellular spaces of the plant which are filled with air.

[1] Any British species of Hydrophilus, Hydrus, Hydrobius or Philhydrus is of suitable form and size for this study.

[2] The Hydrophilid has also a sub-elytral air-space connected laterally with the ventral air-reservoir,

(2) True Aquatics

(*a*) **Anisopterid and Zygopterid Dragonfly Nymphs** (Exopterygota, Odonata). Odonata are divided into two groups, Anisopterids, in which the hind-wings are larger than the fore-wings (this group includes all the thick-bodied dragonflies); and Zygopterids, in which the two pairs of wings are alike (this includes all the thin-bodied forms). The nymphs of the two groups differ in their method of respiration. The Anisopterid has rectal respiration. Water is taken into the rectum through the anus. The walls of the rectum are expanded into numerous ridges or plates which are richly supplied with tracheæ. These latter take the oxygen from the water, which is then expelled from the anus and replaced by a fresh supply.

Open the abdomen and expose the alimentary canal. Note the rich supply of tracheal tubes to the rectum. Cut open the latter and examine the walls. The Zygopterid respires through the body wall (although it is possible that there is a limited capacity for rectal respiration in this group also), but, in order to extend the respiratory surface, there are three lamellæ projecting from the last abdominal segment. Note their attachment, one above and one on each side of the anus, and note the tracheal supply within them. These lamellæ are not essential to the life of the nymph, which can survive even when they have been removed. They are gradually replaced after removal, the first sign of the new ones appearing at the next moult (unless the abscision has taken place just before a moult), and at each successive moult they increase in size.

Both types of nymph have the same type of mouth-parts, the mandibles and maxillæ calling for no remark, the labium being elaborated into a "mask," capable of being projected in front of the mouth for seizing the prey, which consists of live insect larvæ, tadpoles, etc.

(*N.B.*—Although these forms are apneustic, i.e. have no open spiracles and are true aquatics, the nymphs become propneustic in their last stage, a pair of spiracles becoming open.)

(*b*) **Mayfly Nymphs** (Exopterygota, Ephemeroptera). Aquatics in both egg and nymph stages. Some live in running water and these mostly conceal themselves under large stones or amongst the aquatic vegetation. The nymphs breathe by tracheal gills attached laterally to the first seven abdominal segments and these gills are true appendages, homologous with the thoracic legs, etc. The gills vary in form in different species, being filamentous in some and lamellate in others, and they are frequently filamentous when they first appear in species which later have lamellæ. It is said that in some forms, gill filaments are attached to the legs and even to the maxillæ.

In Heptagenia and in other running-water species which live amongst large stones in swift streams, the body is flattened dorso-ventrally, as are also the legs, which turn forwards and are armed each with a strong tarsal claw for holding on to stones. Note also the fringing hairs on the legs which aid the nymph in swimming.

Compare this with the nymph of Ephemera which lives amongst the gravel and with Chlöeon which lives in stagnant water. Note the three many-segmented cerci, a median dorsal one and two laterals.

The mouth-parts are mandibulate and the nymphs feed upon vegetable material.

Examine the mouth-parts.

(*c*) **Stonefly Nymphs** (Exopterygota, Plecoptera (Perlaria)). The insects are aquatic in both egg and nymph stages.

Perla sp. The nymph lives in swift gravelly streams beneath the stones and is a true aquatic, i.e. it breathes by gills and is apneustic. Note its shape, "campodeiform" with long cerci (characteristic of the more primitive Orders and usually absent in the modern ones).

Note the somewhat flattened body with legs spread out and turned forward, the tarsal claws being strong; these characters adapting it for offering but little resistance to the current and for holding on to supports. Respiration is by tracheal gills, of which there are three pairs on the thorax. An examination of the gill-attachments shows that they are Pleurobranchs, i.e. attached to the body and not to the limbs. Note that several aquatic insects have three pairs of thoracic gills, but no insect has three pairs of thoracic spiracles.

In addition to these gills, some Perlids are said to have gills on the head and between the head and the thorax (Hagen, 1880) and there are said to be also gills at the posterior end of the body. Remove a gill, noting the tracheal attachment to the lateral tracheal trunk in the thorax, and make a permanent preparation, staining if desired. Note the extreme fineness of the tubes forming the tuft. The tracheæ given off from the main trunk can be seen branching and re-branching until the branches become so fine that they lose the tænidial thread. The nymph is carnivorous and has typical mandibulate mouth-parts.

(*d*) **Caddis Larva**[1] **and Pupa** (Endopterygota, Trichoptera). (1) Examine a larva, noting the strongly chitinized head and thorax and the thin-walled flexible abdomen. The larva lives in a case built of vegetable materials or stones, sand, shells, etc., according to species, the materials being bound together with silk from the salivary glands, which are highly-developed. The head and thorax of the larva project from the case when the larva crawls about (hence the strong chitinization), while the abdomen is protected by the case.

Examine the 1st abdominal segment and note the three processes capable of being expanded so as to press against the walls of the case. By the expansion

[1] To extract a caddis larva from its case, drop the case containing the living larva into boiling water and continue to boil for three or four minutes. It will then be possible to draw out the larva by seizing the head with a pair of fine forceps and pulling gently. Miall (*The Natural History of Aquatic Insects*, 1895) recommends "a pin, gently inserted into the narrow end of the sheath," the only possible method, if the larva is to be extracted alive, but a somewhat slow process and not to be recommended if a large number of specimens is required.

of these processes, the larva maintains its hold upon the case and carries it about, while the rest of the abdomen is free to move. Movement of the abdomen is essential to create an anterior-to-posterior current of water through the case, for respiration. Should it be necessary for the larva to project far from the case, e.g. when repairing the outside, a pair of chitinous hooks on the last abdominal segment come into action.

Respiration takes place through the filamentous gills on the abdomen, each of which contains a tracheal tube communicating with the lateral tracheal body trunks.

Examine the mouth-parts and note that they are mandibulate. The eyes are simple, as in all larvæ.

(2) Examine a pupa. The full-grown larva fastens its case beneath the water, closes both ends with a mesh of silk and becomes a pupa. The open ends of the case are necessary for the respiration of the pupa, which maintains a current of water through the tube by perpetually waving its abdomen. The mature pupa from which the imago is about to emerge, has to escape from the case beneath the water and reach the surface. It possesses large mandibles which are solely for the purpose of cutting through the silken threads with which the larva closed the anterior end of the tube before it became a pupa.

The imago, as in the Lepidoptera, to which the Trichoptera are related, possesses no mandibles.

VI. THE CIRCULATORY SYSTEM

PLACE a young transparent nymph of an Agrionid dragonfly in a compressor so that it is only slightly pressed and is lying in a natural position. Place it under a low-power microscope and examine the side border of an abdominal segment or a leg or one of the lamellæ at the posterior end and watch the movement of the blood-corpuscles, noting their form and their passage through the spaces between the muscles, with occasional stops at various points. The blood is mainly a nutritive fluid in insects and conveys nutritive materials to all parts of the body, being circulated by the activity of the heart and of certain accessory pumping organs. The working heart will be easily identified in the median dorsal line of the abdomen.

Accessary Circulatory Pumps. Place a living aphid, so called "green-fly," in a compressor and adjust so that the insect cannot move about. Examine the bases of the legs and a pulsating organ will be seen. These organs assist the circulation of the blood and are situated in various parts of the body, but those in the legs are the most easily seen. Note the colourless blood corpuscles moving in the free spaces between the muscles of the leg, down on one side and up on the other.

The general arrangement of the heart and aorta has already been seen in either the cockroach or in Dytiscus or in both but, for details, stained slides are necessary. Although, by the time schedule, there is no time for the student to prepare these, the material has been available if freshly-killed specimens have been used.

The heart of Dytiscus or of the common grasshopper, Stenobothrus, or of either of the water-bugs, Naucoris or Notonecta, is very suitable for this study.

Make out the ostia, the auricular-ventricular openings by which the blood enters the heart, and it may also be possible to see the interventricular valves. Note the alary muscles attached to the pericardial membrane on a wide base below the heart and tapering away laterally to their points of attachment with the body wall. In the pericardium and attached to the pericardial membrane are groups of pericardial cells, nephrocytes, to be seen in almost any mount of the heart. These cells are excretory in function, their action being to eliminate substances which the malpighian tubules cannot deal with. Many of these cells show two nuclei, a characteristic of other groups of cells in other parts of the body performing the same functions.

VII. THE REPRODUCTIVE SYSTEM

THE detailed structure of testis or ovary can only be carried out from series of carefully-prepared sections, but, so far as this course is concerned, all that is necessary is to recognize the two types of ovary, panöistic and meröistic, the latter having two sub-types, polytrophic and acrotrophic.

A reasonable amount can usually be seen by dissecting out the ovary, or one or two ovarioles, clearing, staining and mounting, but longitudinal sections are very much better. Cockroach, grasshopper or stick-insect will provide the material for type 1; a Dytiscid is a good example of type 2; and the water-bugs, Naucoris, Notonecta and Nepa will be suitable for type 3.

(1) **The Panöistic type.** This is the simplest type of ovary, there being no special nutritive cells, nutrition coming from the surrounding epithelial tissue or from egg cells which have failed to achieve their aim and have become follicle cells. It should be possible to recognize the "terminal thread" at the apex of the ovariole by which the egg-tube is attached to its neighbours, all the terminal threads of one ovary uniting into a common ligament. Below the thread is the germarium in which will be seen large nucleated cells and also scattered nuclei in free protoplasm. The lowest part of the tube, the vitellarium, actually constituting most of the ovariole, contains eggs surrounded by follicle cells, but there is no definite limit to any of these three areas.

E.g. Orthoptera, Odonata, etc.

(2) **The Polytrophic type.** Special nutritive cells are present arranged in groups or masses alternating with the developing eggs.

E.g. Hymenoptera, Lepidoptera, Diptera, etc., and many Coleoptera.

(3) **Acrotrophic type.** Nutritive material retained in a large terminal chamber and supplied to the developing eggs by nutritive threads or strands. These strands are not easy to find as they do not run straight and, in a longitudinal section, they are frequently cut obliquely or missed altogether, but there are certain to be some visible showing reasonable lengths.

E.g. Rhynchota, etc. (see Fig. 45 *a*, *b* and *c*).

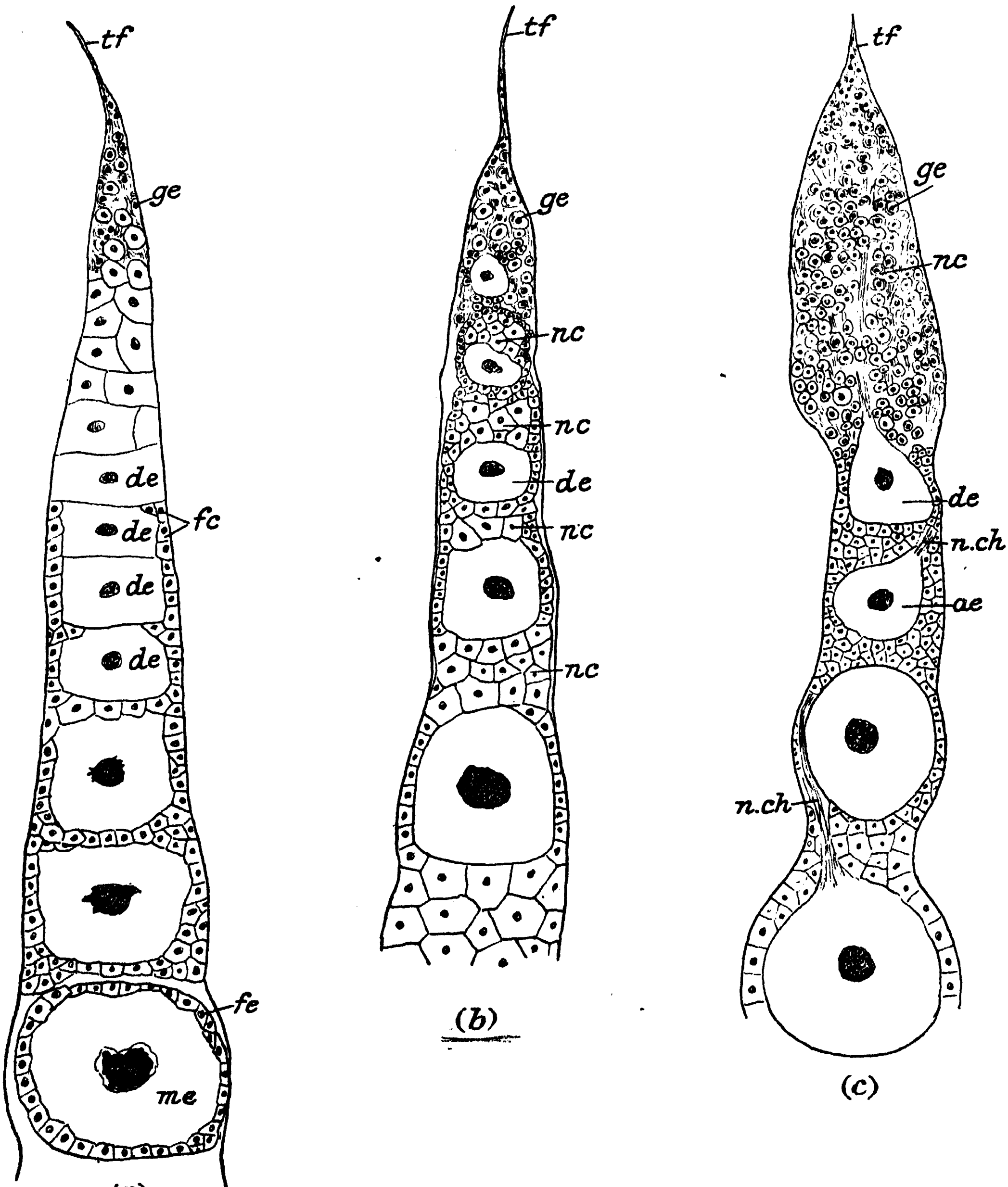

FIG. 45.—Types of Ovary. (*a*) = panöistic; (*b*) = polytrophic; (*c*) = acrotrophic type.

de = developing egg; *fc* = follicle cells; *fe* = follicular epithelium; *ge* = germarium containing potential eggs and nutritive cells; *nc* = nutritive cells; *n.ch* = the nutritive chord running from the nutritive cells in the germarium to the developing eggs; *tf* = the terminal filament of the ovariole.

VIII. EMBRYOLOGY

Some insect eggs are transparent and, in these, it is possible to follow the development of the embryo from its earliest stages to the escape of the nymph or larva from the egg. The eggs of certain water-insects are easily obtained and easily kept alive; e.g. the Agrionid dragonflies bury their eggs in the tissues of aquatic plants and the Dytiscid beetles do the same and both these types will do this in captivity. The beetle *Pelobius tardus* oviposits upon the surface of plants in the water and the Hydrophilids form silken egg-cocoons. The eggs buried in plant-tissue as well as the others can be removed quite easily and all such eggs develop normally upon wet cotton-wool, the minutest trace of methylene blue added to the water apparently aiding in maintaining hygienic conditions.[1]

In the following account, only points easily seen with a low-power microscope are mentioned and, in a course such as this, it is not considered necessary to carry the study any further.

The egg has an anterior pole, that which is last to leave the oviduct, and this end is frequently marked by a small pedicel, the "micropylar structure," surrounding the micropyle. The new-laid egg is a single cell, often very large in comparison with the mother insect. It contains a large nucleus and granular contents, usually with a comparatively clear layer in contact with the chorion or shell.

The first change recognizable is the appearance of a cloudy band along one side in the long axis of the egg. This is the "germ-band" or ventral plate, which broadens out at the anterior end into two large "head-lobes." A narrow depression appears in the median line of the band, the "gastral groove" and the band itself becomes divided by transverse depressions into the "body somites." Development usually begins at the anterior end and spreads backwards, so that the somites and other structures appear at the head end before there is any sign of them farther back. Next there appear globular uprisings in pairs on the somites and these are the buds of the appendages. The ancestral forms from which insects evolved had a pair of appendages upon each segment, and the buds of these still appear in the insect embryo; but all the abdominal ones, excepting

[1] For details as to obtaining the eggs of some of these types, see my papers on "The Life-history of the Agrionid Dragonfly," *Proc. Zool. Soc.*, London, 1909, and "The Life-history of the Water-beetle *Pelobius tardus*," *ibid.*, 1922. In the latter paper there are details as to the treatment of the eggs.

In my paper on "The Life-history of Hydrobius fuscipes, L.," *Trans. Roy. Soc.*, Edinburgh, XLVII, 1910, the figures on Plate III show a series of stages in the development which may be found useful in connection with this study.

the first and last pairs, disappear again after a very short time. The first becomes a globular, cup-like structure with some function unknown, and this pair remains in evidence until the hatching from the egg, when it completely disappears. The last pair become the cerci of the adult insect, where such exist.

Depressions, more or less circular, now appear at each end of the germ-band, one in front of the first pair of appendicular buds and between the head lobes and the other at the posterior end of the band, the mouth in front and the anus behind. Note that the first pair of buds is the future antennæ and that they originate behind the mouth which, however, moves back so as to lie between the second pair of buds, the mandibular buds, so that the antennæ are true appendages, homologous with the others. Behind the mandibles come the maxillæ and then the pair of buds which later unite to form the labium. Note that the transitory appendages of the intercalary segment and the disputed maxillulæ are not likely to be seen. The maxillæ and the labial buds early show a rudiment of the palps.

Ridges now begin to rise up on each side of the developing embryo and these gradually meet over it, forming an inner layer of cells, the "amnion," and an outer layer, the "serosa." The embryo has by now extended so as to occupy the length of the egg and the posterior end is sinking into the yolk and becoming covered by amnion and serosa. The embryo continues to extend and curves so that the "tail" turns round the curve of the posterior end of the egg and over the back of the embryo.

In most forms, of which Dytiscus and Hydrophilus are examples, this partial submergence of the embryo in the yolk is all that takes place, but in some forms, e.g. certain Lepidoptera and certain Hymenoptera (Tenthredinidæ), complete submergence takes place. Again, in most forms, the head of the embryo retains its position near the anterior pole of the egg, but in some forms, e.g. Agrionid Dragonflies, the head moves back and the submerged tail moves round and forward until the embryo has almost reversed its position, a movement known as "involution." In Hydrophilus, Dytiscus, etc., the embryo, after lengthening so that the tail is turned forward, shortens again until the tail once more becomes straight and this stage corresponds with the completed involution of the Agrionid Dragonfly.

The two membranes, amnion and serosa, now break in the median ventral line and roll back up the sides of the embryo, sides which have gradually spread upwards in the process of engulfing the yolk. The membranes continue to contract until they come to lie upon the yolk above the still open back of the embryo. In some forms, e.g. Hydrophilids, these membranes roll up into the form of a tube which was called the "dorsal tube," while in others they concentrate into a shorter form behind the head. Whatever form they take, they ultimately become submerged and absorbed in the yolk, which becomes engulfed in the embryo by the completion of the growth of the two sides, which meet and join in the mid-dorsal line.

After the disappearance of the membranes, the Agrionid embryo once more changes its position in the egg, the head moving forward to the anterior pole and the tail returning to the posterior pole, a process known as "revolution," and the tail then becomes bent beneath the embryo. Similarly, in other forms, the shortening of the body is succeeded by a lengthening, the tail turning beneath the embryo. The eyes in the nymph or the ocelli in the larva and the tracheal system appear about this stage.

All the points mentioned above are easily visible with the aid of a binocular dissecting microscope.

IX. HISTOLOGY

Muscle and fat-body occupy most of the space in the insect and you have, therefore, already seen both. Examine a slide showing muscle and note that it is striped muscle, the only type of muscle found in insects, i.e. both voluntary and involuntary muscle are striped.

Fat-body looks very different in a dissected insect from what it looks in a section after it has gone through all the processes in connection with section-cutting and mounting. Therefore study the slide showing fat-body so as to know what it looks like when, later, you may be trying to interpret what you see in other slides.

The Nervous System is composed of nerve-ganglia and nerve-chords, the ganglia being mainly a mass of nucleated nerve-cells which extend out from the mass as nerve-fibres running together as nerve-chords. Hence no nuclei occur in the chords. Note the appearance of nerve-tissue in section.

Oenocytes are large cells, usually with somewhat granular contents and a large nucleus. They occur in the abdomen, generally not far from the hypoderm or outer layer of body-cells and usually associated with branching tracheæ. They have been variously described as "secreting" and "excreting" cells, and all that can be said is that certain cells, very like them in appearance, contain urates and are known as "urate cells."

Examine a transverse section of a normal salivary gland and of a silk-gland, e.g. from a caterpillar, and note that the structure is the same, three or four cells arranged round the lumen, each cell with a large nucleus.

Examine a similar section of a malpighian tubule and note its general resemblance to a salivary gland section.

Imaginal buds are small groups of cells of imaginal tissue embedded in the larval tissue, from which, at the change from larva to pupa, the pupa (and the future imago) will be constructed. At this stage, the larval tissue breaks down and reconstruction takes place, this being least marked in the lower Endopterygotes, e.g. Neuroptera and Coleoptera, and most complete in the Diptera. These buds of imaginal tissue are most easily seen in the thorax above the bases of the larval legs, but they occur all through the body.

Examine slides of antennal or other sense-organs and note that the main part consists of hairs clustered together in a pit. From the base of each hair there runs a nervule and all these unite together into a nerve running to one of the main ganglia.

Compound eyes, although not correctly described as numbers of ocelli massed together, have, apparently, evolved from ocelli massed together. In the longitudinal section, note the various parts, the basal membrane through which nerves run into the bases of the "ommatidea," the units composing the compound eye, and the central core of each ommatideum, the "rhabdom," showing, on each side, a pigmented cell, one of four surrounding the rhabdom and forming the "retinula." Above the rhabdom is a clear space occupied by a single cell, the cone or lens, or having a division down the middle, depending upon the type of eye, whether it is "eucone" (with a perfect cone) or "acone" (with the cone not developed but consisting of the four cells from which the perfect cone has evolved). Most Coleoptera have acone eyes, but the Pentamerous beetles, many Diptera, etc., have eucone eyes, while some flies have eyes in which there is an intermediate stage, the nuclei of the four cells still remaining, although the walls separating the cells have disappeared.

Above the lens is a flat "cornea," the metamorphosed superficial chitinous layer, and surrounding the rhabdom and lens is a layer of pigmented cells, usually overlapping the retinula cells below them.

Ocelli, found as the only eyes in larvæ and, as additional eyes in various imagines, consist of a layer of pigmented cells, the "retina" upon the basal membrane, overlying which are four clear cells, the "vitrella," the forerunners of the cone of the ommatidea, and surrounding the vitrella, a number of pigmented hypoderm cells; above the vitrella, the external chitinous layer is transparent and forms the "lens."

Chordotonal Organs are structures, usually in touch with the integument, believed to be for the reception of sound. Without going into minute detail, the simplest form consists of a nerve from the segmental ganglionic mass which is connected to the integument and has a bulging portion containing a vibratory apparatus. The nerve is usually pulled out of the straight course and stretched by a ligament. These simple organs are usually found in twos or threes where they occur.

The living larva of Corethra, the so-called "phantom larva," shows these organs very well, if placed on its side in a compressor. Three arranged parallel to one another can be seen in one or more of the posterior abdominal segments.

A more complex "auditory" organ is found in various insects where a special tympanum exists in the integument, e.g. in the Grasshoppers (Acridiidæ), where a single vibratory capsule lies behind it or in the Tettigoniidæ (Long-horned Grasshoppers), where a series of capsules of varying size exists, suggesting that simple tunes might be appreciated instead of mere general noise.

X. *THE ORDERS OF INSECTS*

A STUDY arranged with the object of familiarizing the student with the general appearance of various representatives of the Orders of insects. The few notes appended to the different examples are solely for the purpose of stimulating interest in the examples.

(1) **Examples of the Protura,** included by some as an Order of insects but, for several reasons, to be regarded as outside them. For instance, there are no antennæ and growth is by intercalation of segments (anamorphosis) as in the Myriapoda, a process never found in insects, except in antennal, and possibly cercal, growth in certain forms.

Protura are readily obtained by the use of the Berlese funnel. They are abundant in moist peaty soil and are not confined to peat.

(2) **Examples of the Thysanura.** There are four families in the Order and Machilis, Lepisma, Campodea and Japyx provide an example of each family. There is no metamorphosis, there are no wings and the thoracic segments and the ten or eleven abdominal segments look very much alike. The insect is elongate, mostly with long antennæ and long cerci; the latter sometimes modified to forceps in the Japygidæ.

(3) **Examples of the Collembola.** One of the lowest Orders of insects but higher than the Thysanura, in that the reduction of abdominal segments, a characteristic happening all through the insects, has taken place, there being six or fewer segments. The respiratory system is very primitive, certain forms, apparently, being without tracheæ.

The Lipuridæ are probably the simplest forms, found chiefly in decaying vegetable matter, higher forms possessing a leaping apparatus on the ventral side of the body. All members of the Order have a peculiar "ventral tube" (see *Cambridge Natural History*, vol. v, p. 192).

(4) **Examples of the Anoplura**

Sub-Order Mallophaga: The Biting Lice. Sometimes called Bird-lice because the great majority are found upon birds, although there are species upon dogs, cats, sheep, etc.

Harrison, L., has suggested that an examination of the Mallophaga upon different kinds of birds would be useful in connection with tracing the evolution of the latter. (See "The Mallophaga as a possible clue to Bird Phylogeny," *Australian Zoologist*, Royal Society of New South Wales, Vol. I, Pt. 1, June,

1914, and "The Relation of the Phylogeny of the Parasite to that of the Host," *British Association*, Sect. D. (Zoology), Manchester, 1915.

Sub-Order Siphunculata: Sucking Lice. Apparently all members of this Sub-Order feed upon the blood of mammals. At one time associated with the Rhynchota, of which they were regarded as forms degenerated by long parasitism, but they are now recognized as being distinct exopterygotes in which the wings have disappeared. They were placed by Sharp in the group Anapterygota, which has since been broken up amongst the Exo- and Endopterygota, having been recognized as artificial. (See Sharp, D., "Some points in the Classification of Insecta Hexapoda," *Proc.*, 4th International Congress of Zoology, 1899, pp. 246–9.)

(5) **Examples of the Corrodentia,** by some now regarded as containing three separate Orders, Isoptera, Psocoptera and Embioptera. (See Imms, A. D., *Text-book of Entomology.*)

The Psocids are known as "Book-lice," because some of them frequent old books, and as "Death-watches," because they make a ticking noise. Most of the species are winged, but apterous kinds exist. Plentiful supplies can be obtained by beating trees, etc.

The Embiids are tropical insects remarkable for their elementary social habits and their silk-spinning capabilities. The silk glands are in the anterior tarsi, a condition only known elsewhere in the insects in certain flies in the family Empidæ.

The Termites, another tropical group, show every grade of social life from a simple one, little more than mere gregariousness of the members of a small family, to a highly complex division of labour between the members of a family of many thousands. Although this is one of the more primitive Orders, the social life is as highly developed as in the Hymenoptera. Note the different form of the different castes.

Note that the definition of a social insect is "an insect in which the members of the family do something for the common good."

(6) **Examples of the Rhynchota (Hemiptera)** [1]

1. *Cimex lectularius*, the bed-bug. An insect only found associated with man and said not to occur amongst savages! In connection with its parasitic habits its wings have degenerated to small pads.

Note its dorso-ventral flattening, which enables it to conceal itself in narrow cracks.

2. *Scale insects* belonging to the family Coccidæ, to show the exceedingly degenerate condition of the female, a condition associated with its sedentary

[1] The name "Hemiptera," meaning half-winged, actually suits only one of the two Sub-Orders of which this Order consists, whereas the name Rhynchota, meaning "snout-possessors," is a true name for the whole Order. In America, however, the two Sub-Orders have been made into separate Orders, the Hemiptera and the Homoptera. Darwin divided Naturalists into "wholehoggers" and "hairsplitters."

life, there being nothing to identify it as an insect, excepting the mouth-parts, which are typical bug mouth-parts, and the single anal-plate on the back. The younger stages and the male are, however, easily recognizable as insects, possessing legs and other insect characters.

3. *Aphides* or "green-fly," belonging to the family Aphididæ (or Aphidæ), with typical bug mouth-parts and usually with long legs and long antennæ. Interesting on account of their life-cycle which usually shows an alternation of generations, a sexual one (which is perhaps gradually disappearing), giving rise to a parthenogenetic one which may carry on parthenogenetic reproduction through a number of generations before returning to the sexual phase.

(7) **Examples of the Neuroptera**

1. *Coniopteryx*, of the family Coniopterygidæ, at one time included as a sub-family of the Hemerobiidæ, which they resemble in many respects. The larvæ have piercing mouth-parts, the piercing organs presumably being the mandibles and maxillæ together, as in Myrmeleonids, Hemerobiids, etc. The insects are all minute and mostly excrete a powdery wax which covers their bodies.

2. Examine the mouth-parts of a *Myrmeleon larva*, to see what is meant by the sentence above with regard to the mouth-parts of Coniopterygids. Adult Myrmeleonids (Ant lions) resemble dragonflies in general appearance, but, whereas the former live under arid conditions and have four stages in their life-history, the latter have only three stages and the nymph is aquatic.

3. *The Hemerobiids*, are hairy-winged insects which might be mistaken for small brown moths and have been called "brown lacewings." The larvæ are interesting in that they feed on aphids like their relations the Chrysopids, the "lace-wings." In the latter family the larvæ cover their bodies with the skins of the sucked aphids, a statement which has also been made of the Hemerobiid larvæ, but which has since been disputed.

4. *The Snake-flies*, *Raphidia*, have the larva and adult very much alike in general appearance except that the former has no wings (which, of course, develop in pockets in the sides of the thorax in larvæ). The snake-fly larva is found in rotten wood. It is very active and wriggles backwards as quickly as forwards. It is "campodeiform," i.e. it is long and narrow and has long (running) legs and thus resembles, in a general way, the Thysanuran, Campodea, as do all the larvæ of this Order: an indication that this is one of the more primitive Orders of the Endopterygota.

(8) **Examples of the Strepsiptera**, an Order which has close affinities with the Coleoptera and should possibly be treated as a sub-Order of that Order. The males, which greatly resemble minute beetles, are capable of flight and are exceedingly rapid in their movements. The females never leave the bodies of bees and wasps, upon which they are parasitic. The larvæ undergo hypermetamorphosis, i.e. they change their form during growth. The

first stage is an active "triungulin," so called because it possesses three tarsal claws on each leg. When first discovered, and before its life-history had been investigated, it was thought to be an imaginal stage of a primitive insect and was named "triungulinus" on account of its three claws.

(9) **Examples of the Thysanoptera:** "Fringe-wings." At one time regarded as Rhynchota and probably related to that Order, in spite of the fact that they are placed in the Endopterygota. The metamorphosis is peculiar. The full-grown "larva" passes into a resting stage which, although not a true pupal instar, seems to correspond to it; but a similar stage occurs in the life-history of the male Coccid in the Rhynchota!

The mouth-parts are peculiar, since they are asymmetrical, though apparently not in all species. (See the *Cambridge Natural History*, VI, pp. 526–31.)

(10) **Examples of the Diptera**

1. *The "Sheep-ked," Melophagus ovinus* of the family Hippoboscidæ, one of the families of the Diptera Pupipara, a fly specially adapted for crawling about on the skin of the sheep, on the blood of which it feeds. Owing to its parasitic habit it has lost its wings.

2. *The "Bee-louse," Braula*, of the family Braulidæ, another Pupiparous fly, parasitic upon bees. Another parasite which has lost its wings and which has very imperfect eyes.

3. *The larva and pupa of Simulium*, a fly which passes all except its imaginal condition in the water, usually in rapidly flowing streams. Both larva and pupa are attached, by the posterior end, to stones. The fringes on the head of the larva serve to bring the food to the mouth. The pupæ are fixed in a semi-cocoon, from which they project, and from the prothorax there project a pair of feathery respiratory processes.

(11) **Examples of the Aphaniptera** (Siphonaptera). In the imago note the piercing and sucking mouth-parts, absence of wings, the large coxæ (which are the "leaping" part of the leg), and the fringes of spines on body and legs which enable the insect to work its way through very narrow spaces. The flea is flattened laterally, and thus differs from almost all other insects which are dorso-ventrally flattened, if at all. Note the absence of legs in the larvæ, as in all Dipterous larvæ, to which the Aphaniptera are closely related.

XI. A SYLLABUS OF AN ADVANCED COURSE

(two hour periods), worked upon the notes already given

Note.—It will be understood, first, that all the work mentioned in this list is not necessarily carried out. Classes vary somewhat in their rate of getting through a programme, and experience shows that it is always good policy to keep the students fully occupied. Secondly, material is not always available; specimens cannot be obtained or slides have been broken which are not easily replaced, and omissions from the full programme give a less unfavourable impression to the class than the addition of stop-gaps. The dissection of the larva of Dytiscus is a reserve.

1 and 2. Dytiscus, External character.

3 to 6. Dissection of Dytiscus.

7. Machilis, for preparation of the mouth-parts. Slides of Orthopteran mouth-parts. Nymph and Imago of Dragonfly for preparation of mouth-parts.

8. Slides of mouth-parts of Ephemera vulgata or other species. Specimens of Cicada or of Nepa, Notonecta or Naucoris for preparation of mouth-parts.

9. Slides of larval mouth-parts of Myrmeleon, Chrysopa or similar Neuropteron. Melolontha or Rhizotrogus and a Scarabæid larva for preparation of mouth-parts.

10. Elaterid larva (wireworm) for preparation of mouth-parts. Slides of Copris, etc., mouth-parts for mandible study. Slides of mouth-parts of a Weevil.

11. Dytiscus larva for preparation of mouth-parts. Slides of mouth-parts of Carabid or Cicindelid beetle and of an anthophilous Telephorid or Cerambycid. Slides of Melöids, Nemognatha and Zonitodema mouth-parts and of larvæ of Glow-worm (Lampyrid) and of Gyrinus.

12. Butterfly or Moth (Noctuid) for preparation of mouth-parts. Slides of Micropterygid mouth-parts.

13. Vespa or Bombus for preparation of mouth-parts. Slides of Bombus or Vespa and Apis.

14. Evolution of mouth-parts in Hymenoptera: (*a*) The Maxilla. Slides of Maxilla of Cephid and Tenthredinid Sawflies, Vespa, Andrena, Melecta, Nomada, Panurgus, Halictus, Macropis, Dasypoda, Bombus, Coptorthosoma, Apis; (*b*) The Ligula in Bees. Slides of Labium of Colletes, Prosopis, Sphecodes, Macropis, Andrena, Cilissa, Halictus, Dasypoda, Nomada, Panurgus, Melecta, Eucera, Coptorthosoma, Bombus, Apis.

The working of the mouth-parts. Bombus or Apis.

15. Syrphid fly for preparation of mouth-parts. Slides of mouth-parts of Culex and Anopheles, male and female, Tabanid, Empid, Calliphora, Stomoxys, Glossina, Asilid.

16. Weché's Theory. Slides of mouth-parts of Empid, Syrphid, Tabanid, Calliphora, Stomoxys, Sepsid (Nemopoda cylindrica), Opomyzid (Baleoptera venusta), Borborid (Sphærocera subsaltans), Bibionid (Dilophus febrilis).

17. Wing-coupling Apparatus. Slides of wings of Panorpa, Hemerobiid or Chrysopid, Caddis, Micropterygid, Hepialid, Noctuid, Sphingid, Vespa, Cicada or Notonecta.

18. A Study of Legs. Coccinellid, Cerambycid and Curculionid beetles for mounting legs. Ichneumonid for trochanter. Male and female Dytiscid for mounting legs, or slides. Muscid tarsus (empodium), also Asilid and Leptid tarsi, or slides. Vespa, Odynerus or other Hymenopteron, anterior tarsus for "antenna-cleaner." Slides of tarsi of Curculionid and of triungulin of Melöe. Legs of Panorpa or Caddis for Coxa vera and meron.

19. Respiration. Dytiscid and Hydrophilid beetle for external comparison; also larva of one or other. Larva of Culex or Anopheles and Eristalis (Rat-tailed maggot). Larva of Donaciid beetle or slide. Slides of tracheæ of caterpillar. Spiracle and closing-apparatus of Dytiscus. Slides of spiracles of Melolontha or Geotrupes or other Scarabæid larva. Slides of spiracles of Elaterid beetle and of Weevil.

20. Aquatic Respiration. Anisopterid and Zygopterid Dragonfly nymphs for examination; also slides of rectum of the former. Nymphs of a Mayfly, e.g. Heptagenia, or slides. Caddis larvæ for examination and slides of pupa. Perlid nymphs or slides.

21. Circulatory and Reproductive Systems. Living specimens of young stages of nymphs of Agrionid dragonflies (obtainable at all times of the year because the nymph takes two or three years to grow up) to see the circulation of the blood. Slides of heart and pericardium (and pericardial cells, nephrocytes) of a grasshopper. Alary muscles of Dytiscus or Naucoris or Notonecta (and pericardial cells). Living Aphides for accessory circulatory pumps. Slides of ovary of grasshopper or cockroach (Panöistic type); of a Dytiscid (Polytrophic type); of Naucoris, Notonecta or Nepa (Acrotrophic type).

22. Histology. Slides showing muscle, fat-body, nerve ganglia and chords, œnocytes, salivary glands, malpighian tubules, imaginal buds, sense-organs (e.g. antennal), ocelli and compound eyes, chordotonal organs.

Through most of the summer the transparent "phantom" larvæ of Corethra are obtainable in ponds, and these provide fresh material for simple chordotonal organs.

Embryology. In early summer living eggs of Dytiscid or Hydrophilid beetles can be found and will show various stages of development. Slides of

transverse and longitudinal sections of one of these types and of eggs of Agrionid dragonfly showing involution and revolution.

23 and 24. The Orders of Insects. Slides of Protura, Machilis, Lepisma, Campodea and Japyx, A Collembolan (Orchesella, Lipura, Podura, etc.). Example of Mallophaga and a body-louse, a Psocid, a Thrips, an Embiid, a Bed-bug, Coccids, a Coniopterygid, Rhaphidia, Myrmeleon larva mouth-parts, Hemerobiid larva and Chrysopa larva, Stylops, Triungulin of Melöid beetle, Melophagus ovinus, Braula, Simulium larvæ and pupæ. Flea and larva. Examples of castes of Termites, Psocid imagines. Scale insects on plant, "Green fly," Myrmeleon imagines, and Snake-fly, etc.

PART III

THE PRINCIPLES OF SYSTEMATIC ENTOMOLOGY

INTRODUCTION

PART III commences, as the previous parts, with the external characters and dissection of an insect and then becomes a "Special Morphology" Course, the object of this part being to make the student acquainted with those characters which are of importance in systematic work, but only so far as determining the family of the insect is concerned. For more detailed work, it is obvious that the special systematic books dealing with the different Orders must be used.

Since, in the winged insects, the wing-venation is of such great importance, this part of the work begins with a study of wings of Diptera, Hymenoptera and Lepidoptera, the three Orders in which venation plays a specially important part.

It may be thought that this chapter should have been split up and distributed to the special morphology of the three Orders involved. In my Course, however, the practicals upon this subject followed lectures upon wing-venation, with which Part III of the lecture course commenced, and others may prefer to deal with the subject in the same way.

In this part I have included two keys, one for the determination of the larvæ of Coleoptera and the other for the determination of the larvæ of Lepidoptera. The latter is based upon Fracker's "Classification of Lepidopterous Larvæ" (*Illinois Biological Monographs*, July, 1915). The key for the beetle larvæ is based upon a much older paper by A. D. Macgillivray, "Aquatic Chrysomelidæ and a Table of the Families of Coleopterous Larvæ," published in 1903. Although I have expanded and varied the original, my key is admittedly very imperfect, not only because it includes no more than about fifty families, but also because it has only been tested for a few species and it may be taken as certain that other species will not work out to their own families. It was only constructed, in the absence of a better one, to cover the species provided for determination by the class, but it may prove of use to others until the appearance of the promised Monograph upon this subject by Böving and Craighead, which will undoubtedly supersede all previous attempts in this direction.[1]

[1] While this book is passing through the Press, the *Illustrated Synopsis of Principal Larval Forms of Coleoptera*, by Böving and Craighead, has been published.

I. THE GRASSHOPPER

THE following notes are founded upon work done on the common British Stenobothrus, but, excepting in certain small details, they apply to large Locustids[1] (Acridiids) received from India, Egypt and the United States. The drawings are mainly from foreign specimens, which differ in small details from Stenobothrus.

Note the general form of the insect, long, slightly compressed laterally, with long legs, especially the third pair, and if mature, with long narrow wings folded roof-like over the back.

The Head. Note the form, with the "face" anterior, looking slightly downward (not distinctly ventral as in some members of the family (e.g. Tryxalides) nor dorsal as in many insects). Note that two groups of grasshoppers (Tryxalides and Ædipodides) are separated partly on the character of the position of the face. In the former it is "declivous" while in the latter it looks forward. In the Acridiides it varies. Note the position of the antennæ on the front of the head, each seated in a depression, the "antennal fossa." Above the fossæ, note a pair of short depressions lying across the top of the face, the "foveoles." The position and character of these is useful, as one of the characters for separating three sub-groups of the family.

The Pyrgomorphides have foveoles contiguous and at the apex of the "face"; the Pemphagides and Acridiides have foveoles not at the apex. In the former they are superior and open behind, while in the latter they are lateral or inferior and closed behind or they may be obsolete. Draw an antenna, noting that it is composed of numerous (about twenty-five) segments. This is

[1] In older books upon the Orthoptera, the "short-horned" grasshoppers are classed as Acridiidæ and the "long-horned" species as Locustidæ. Since all the forms popularly known as "locusts" belong to the "short-horned" family, the name for the "long-horned" species was unfortunate and, by common consent, it was dropped and the name Phasgonuridæ substituted. In 1921, Uvarov * showed that this latter name was wrong and approved of Tettigoniidæ, and he further showed that the name Locusta was used by Linnæus in connection with certain short-horned species.

Some of us, therefore, assumed that the family name Locustidæ should replace Acridiidæ and were somewhat surprised, when Uvarov published his Monograph on Locusts and Grasshoppers,† that the name Acridiidæ appeared as before and no mention was made of the name Locustidæ. I now understand that the author's opinion is that the latter name should be suppressed and that the short-horned group is correctly called Acridiidæ.

* Uvarov, B. P., "A Revision of the genus Locusta, L. (Pachytylus, Fieb.)," etc., *Bull. Ent. Research*, XII, 1921, pp. 135–63.

† Uvarov, B. P., "Locusts and Grasshoppers.," *Imperial Bureau of Entomology*, 1928, 352 pp.

comparatively short and the length of the antenna is one of the characters separating the Acridiidæ, "short-horned" grasshoppers, from the Tettigoniidæ (wrongly called "Phasgonuridæ" and "Locustidæ"), the "long-horned grasshoppers." (Within the Acridiidæ, the length of the antenna relative to the length of the anterior femur is used as a character for dividing up all but a small proportion of the species into two groups, one of which has antennæ longer, and the other shorter, than the anterior femur.) Note the sutures of the head, separating labrum, clypeus and frons. Draw a front view of the head showing the position of the antennæ, foveoles, and of three somewhat oval semi-transparent areas, the ocelli. Note the slight ridges on the vertex. The shape of the front and upper parts of the head are of systematic importance (see Fig. 46). Look at the side view of the head so as to observe the relationship of the mouth-parts. Draw, if time permits.

Remove part of a compound eye, examine under the microscope and draw a few facets. Remove the mouth-parts. Examine the labrum and notice the membranous lining, the epipharynx.

Mount and draw the mandibles, a maxilla and the labium, after boiling in potash. Note that the maxilla has a small basal piece, the cardo (usually composed of two parts), and a large stipes, while the labium has only one piece, the mentum, to represent both cardo and stipes. (*N.B.*—In many insects cardo and stipes of the labium are distinct as "submentum" and "mentum.")

Examine and draw the cervical sclerites, sometimes called "cervicum" or "Labial segment" (there are two lateral pairs, one large and conspicuous and one small and inconspicuous).[1]

Thorax. Note the division of the thorax into pro-, meso- and meta-segments. Pin the insect down dorsal side uppermost, and spread the wings so as to show the dorsum of the meso- and meta-thorax.

Draw a dorsal view of the thoracic segments, first of the prothorax and then, after cutting away the backwardly-projecting portion of its notum, of the other two.

The pronotum is of systematic importance; in one group (Tettigides) it is elongated posteriorly so as to cover the whole body; in another (Pneumorides) it covers half the dorsum.

In the meso- and meta-nota (see Fig. 47) certain areas are recognizable. A narrow edge along the front and the anterior side-pieces associated with it constitute the prescutum; the middle main part of the segment is the scutum, while the posterior part, extending across the segment, is the scutellum. Label all these parts in your drawing. (*N.B.*—In most Orders of insects there is a further piece behind the scutellum, the postnotum, but this does not exist in the Orthoptera.) Note that, from the scutellum there projects out on each side a narrow chitinous strip attached to the membrane of the wing. This is the axillary chord and the membrane which it encloses is the axillary mem-

[1] The number of cervical sclerites differs in different species.

brane, and in this, between the thorax and wing proper, are several small axillary sclerites.

In the Cockroach, these axillary sclerites were merely mentioned, while in Dytiscus, figures were given in which they appeared. In that type, they were easy to determine but, in many cases, although it may be possible to recognize some parts of them, it is extremely difficult to make out their limits and, should the student's drawings not agree with those given in the figures, it will not necessarily follow

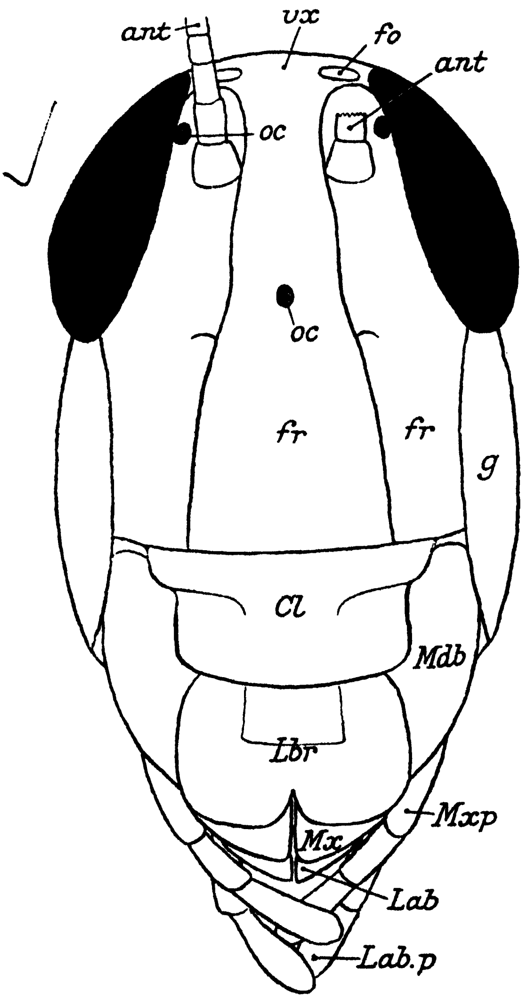

FIG. 46.—The "Face" of the Grasshopper.

ant = antenna cut off; *Cl* = clypeus; *fo* = foveole; *fr* = frons; *g* = gena; *Lab* = apex of galea of labium; *Lab.p* = lab. palp; *Lbr* = labrum; *Mdb* = mandible; *Mx* = apex of maxilla; *Mxp* = Max. palp; *oc* = ocellus; *vx* = vertex of head.

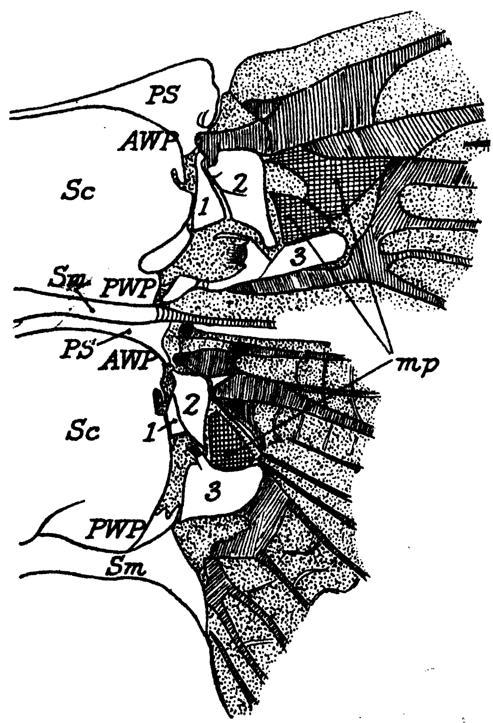

FIG. 47.—Grasshopper. Meso- and meta-thoracic nota with wing attachments, showing axillary sclerites, 1, 2, 3, and the median plates *mp*.

AWP and *PWP* = ant- and post-notal processes; *PS* = prescutum; *Sc* = scutum; *Sm* = scutellum.

that he is wrong. Some assistance can be got by knowing the wing-veins with which these sclerites are associated and a detailed statement on this is deferred until after the study of wing-venation, and will be found in the chapter on the external morphology of the Lepidoptera on pp. 146, 147.

The sclerites are usually three in number and, when four are present, it is usually obvious that the fourth is a piece broken off from the third (see Cicada in Fig. 75). In many cases, however, two other plates may be found between these sclerites and the bases of the wing-veins, and it is reasonable to assume that these "median plates" are pieces separated off from the veins, an explanation which probably accounts for the origin of the axillary sclerites also. When present, these median plates lie, one outside the 2nd sclerite and the other associated with both the 2nd and 3rd sclerites. They may both be absent, as in Dytiscus, or one may be present, as in the metathorax of the Grasshopper. They may appear to be part of the axillary sclerites, as in the Grasshopper where, in the mesothorax, the upper median is joined by a narrow neck with the 2nd sclerite while the lower median, both in meso- and metathorax, appears to be part of the 3rd sclerite.

The Wings. Note that the anterior and posterior pairs of wings differ. The front pair, known as "tegmina," attached to the mesothorax, are stiff and narrow and, when at rest, lie along the dorsum, acting as a covering for the 2nd pair and also for the body. Note the veins on the fore-wing and, among the projecting longitudinal veins, note that one is rather more marked and has a sharp edge. This is scarcely noticeable in the female, but in the male it is part of the musical apparatus. The posterior pair of wings, attached to the metathorax, are thin and transparent and, in a state of rest, are folded fanwise. Note the character of the venation in both pairs of wings, the veins being straight with many cross branches. This venation is characteristic of the order Orthoptera and the fan-like folding is usual throughout the Order.

The Pleurites. Lift the insect and re-pin it on its side, raising the wings so as to expose the sides of the thoracic segments. Draw the side view.

Note that the notum of the prothorax extends over the sides so that no lateral sclerites exist on that segment, excepting a small triangular piece in front of the base of the leg, the trochantin or possibly the episternum. Note that the wings are attached between tergum and pleuron of the meso- and metathorax, while the legs are attached between pleuron and sternum.

Note that the point of attachment of the wing lies at one end of a well-marked descending suture, while the point of attachment of the leg lies at the other end of that suture, the pleural suture, dividing the anterior main sclerite of the pleuron, the episternum, from the posterior sclerite, the epimeron (see Fig. 48).

The pleural wing-process projects upwards from the epimeron and, in the membrane in front of it, lie two small sclerites while in the membrane behind it lies one (see Fig. 49). These are the "epipleurites" of Comstock ("paraptera" of some authors), the anterior ones being the "basalares" and the posterior, the "subalare." They never exceed four in number in any insect, two anterior and two posterior, and often, the only basalare present is

fused with the pleural wing-process. Reference should now be made to Dytiscus and Fig. 17, where the two epipleurites are shown, although little was said about them in the notes.

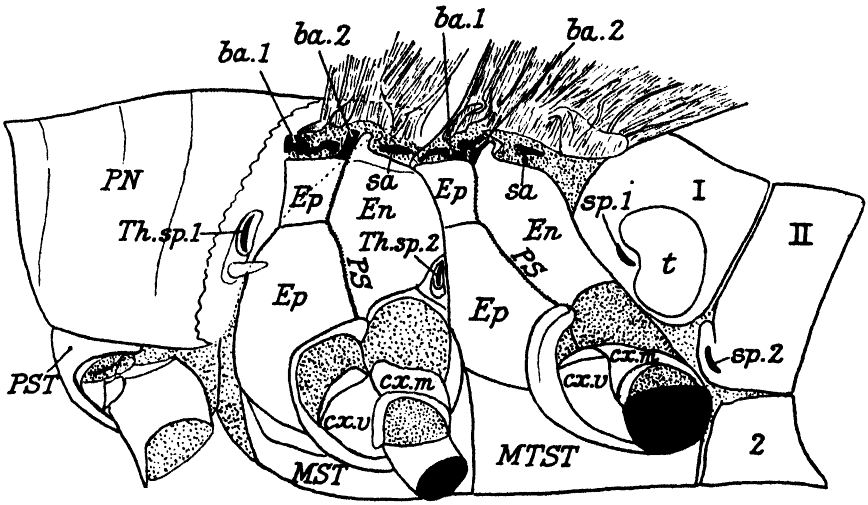

FIG. 48.—Grasshopper. Side view of thorax and anterior abdominal segments.

The epipleurites (*ba* and *sa*) are in black, and an enlarged view of them is given in Fig. 49; *cx.v* and *cx.m* = coxa vera and coxa meron; *Ep* and *En* = the episternum and epimeron; *MST* = meso-sternum; *MTST* = meta-sternum; *PS* = plural suture; *PN* = pronotum, the posterior flap cut off to expose other parts; *PST* = prosternum; *sp.* 1 and 2 = 1st and 2nd abdominal spiracles; *t* = tympanum; *Th.sp.* 1 and 2 = 1st and 2nd thoracic spiracles; I, II = terga of 1st and 2nd abdominal segments; 2 = 2nd abdominal sternum.

Note the spiracles and their situation on the pleura; one, the 1st thoracic, in the membrane between pronotum and episternum of the mesothorax,

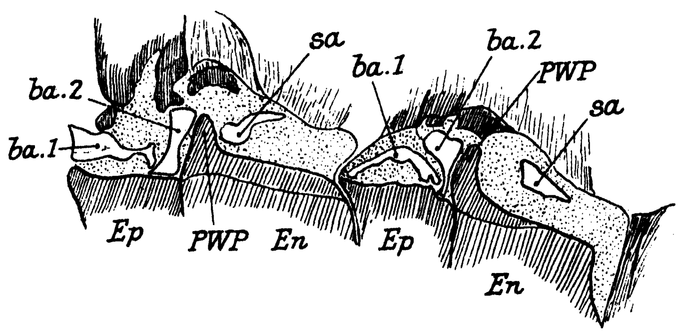

FIG. 49.—Grasshopper. The meso- and meta-thoracic epipleurites; two basalares (*ba.*1 and 2) in front of the pleural wing process (*PWP*) and one subalare (*sa*) behind it.

Ep and *En* = episternum and epimeron of the two pleura.

covered by the backward projection of the pronotum; the other, the 2nd thoracic, between the epimeron of the meso- and epi-sternum of the meta-thorax, about half-way up the side.

The Sterna. Lift the insect and re-pin it, ventral side up, and examine and draw the thoracic sterna. The prosternum is small and bears a piece which projects backwards from its anterior margin over the ventral surface of the segment. All those Acridiids with this backwardly-turned piece are described as having the prosternum "armed," while those without it have the prosternum "unarmed." In many cases this piece is very large. (This character is of systematic importance as it separates all but a small proportion of the members of the family into two groups. The Tryxalides, Pamphagides and Acridiides have it armed.)

In the Tettigides and those other groups in which the antennæ are shorter than the anterior femora (Pneumonides, Mastachides and Proscipides), it is of no systematic importance.

The mesosternum is a large broad sclerite excised in its posterior margin, receiving a forwardly-projecting portion of the metasternum. On each side, at its posterior corners, it is excised to receive the coxa of the middle leg, which also cuts out the anterior corner of the metasternal plate.

The metasternum is also a large sclerite and has a small excision in the middle of the posterior margin which receives a small anterior projection of the 1st abdominal segment. This excision is somewhat larger in the female than in the male and perhaps contains a sense-organ.[1] The posterior angles of the metasternum are cut off and in their place is a triangular plate between the main sclerite and the coxa of the hind-leg. This plate is perhaps the trochantin.

The Legs. Remove one of the front legs, making certain that the basal segment is not left attached to the body. Draw side view. Note the five divisions: Coxa (basal piece), Trochanter (small), Femur, Tibia, and 3-segmented Tarsus.

Examine the tarsus from the ventral side.

Note that the basal and the next segment each carries two transversely-placed pads, making the tarsus look as if it were 5-segmented. Note the pair of claws at the end of the apical segment and the pad (pulvillus, also called "onychium") between them.

This pad is of systematic importance since one group of the family (i.e. Tettigides) is recognized as being without it. Draw a ventral view of the tarsus.

Note the character of the posterior legs, which are specialized for jumping.

Note the normal position of the femur in a state of rest, with its inner face against the anterior wing.

[1] Depending upon the species examined, there may or may not be visible certain pits in the prosternum and in the forwardly-projecting part of the metasternum and of the 1st abdominal segment. These pits may be points where inpushings of the exoskeleton are forming internal apodemes or, in some cases, may be sense-organs.

The capacity for jumping by means of such legs is common to the Acridiidæ, Tettigoniidæ and Gryllidæ, which are known as Orthoptera-Saltatoria, as opposed to the non-jumping Orthoptera-Cursoria.

Remove one of the hind-legs and, on the inner face, notice three longitudinal ridges. On the middle one, commencing near the base and extending about half-way along, is a series of small ridges which constitute one half of the musical apparatus (*vide* the wings, p. 99). In the female these ridges are visible but are much smaller than in the male.

The Abdomen of the Female. Take a female specimen, lay it on its side and make a drawing of the abdominal segments.

Note ten segments marked in terga, 9 and 10 being indistinctly separated and followed by the "suranal" (supra-anal) plate, the identity of which as a tergum of a segment is disputed.[1] Immediately below the suranal plate is the anus and, on each side, note a "paraproct" (podical plate), on the outer side of which and attached to the 10th tergum is a short cercus. The identity of the paraprocts is obscure, but there seems to be some evidence that they include the sternum of segment 10.[1]

On the 1st tergum at each side, note the large "ear" represented by a chitinous ring with the surface covered in except for a wide slit. The tympanum (which will be seen on dissection) lies below this slit. (In Acridiidæ the tympanum is sometimes entirely superficial, a membrane surrounded by a chitinous ring (e.g. in the species in Fig. 48), in other cases it is somewhat depressed with a lip of chitin projecting slightly over it, while in other cases again it is deeply set, there being an extra-tympanic cavity (external ear) covered in with chitin, except for a broad slit, e.g. Stenobothrus, Mecostethus).

Note the situation of this auditory organ on the 1st abdominal segment. This is characteristic of the Acridiidæ, while in the Tettigoniidæ the auditory organs are on the anterior tibiæ.

The Pleura. There are no pleural sclerites, the pleura being membranous or perhaps partly fused with the terga, since the spiracles are in the latter.

The Abdominal Spiracles. As just mentioned, the spiracles lie in the terga. The first will be found (in Stenobothrus), inside the entrance to the tympanic cavity at its upper, anterior end and in a small triangle of dark chitin. The second is considerably below the first. Follow round the rim of the entrance to the tympanal cavity to where it comes close to the anterior border of the 2nd segment. Just below this the tergum of the latter segment projects forward in a small lobe and the spiracle is in this lobe (see Fig. 48). The other six spiracles are in the terga of segments 3 to 8, not far from the pleural margin and near the anterior border.

The Female Genital Armature. As in most insects, this is composed of

[1] See Walker, E. M., "The Terminal Abdominal Structures of Orthopteroid Insects," *Ann. Ent. Soc.*, America, XII, 1919, p. 283, and XV, 1922, p. 7.

three pairs of structures arising from the sterna of segments 8 and 9. A pair of buds on the former gives rise to the true ventral pair and a pair of buds on the latter gives rise to two pairs, the lower of which are the coxites of the segment and form the lateral lobes, the upper pair forming the dorsal lobes.

The structures themselves are of a simple type and easily made out, but their relationships to their segments are obscure. The 8th segment is complete with large tergum and sternum and the tergum of the 9th segment is easily recognized, although it is fused with that of the 10th. The 9th sternum is membranous, so that the two pairs of large genital lobes arise out of mem-

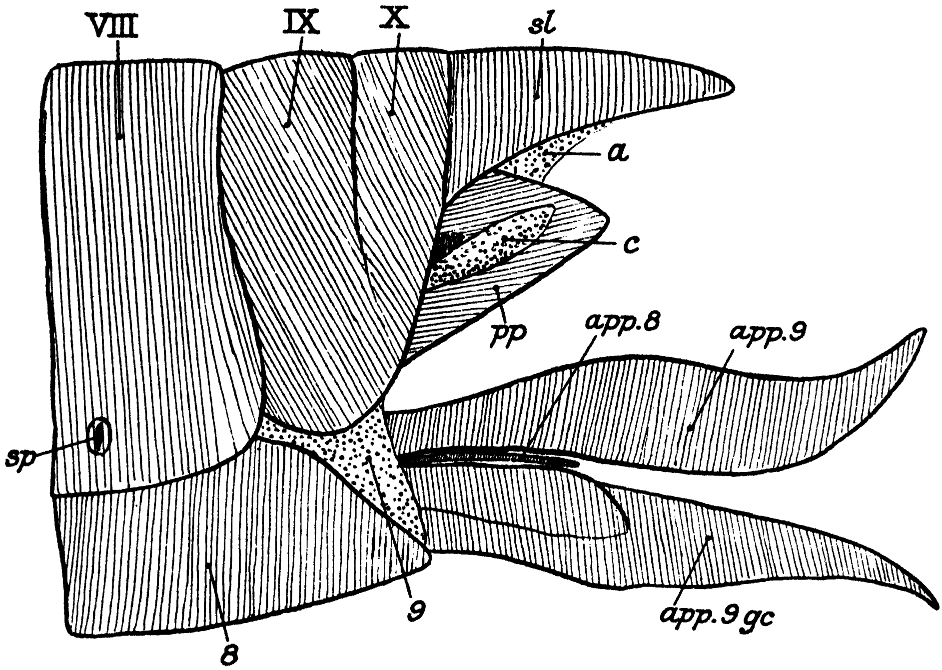

FIG. 50.—Grasshopper ♀. Lateral view of apical abdominal segments and the gonapophyses. *a* = anus; *app*.8 = vestigial appendages of segment 8; *app*.9 and *app*.9*gc* = the appendages of segment 9 (the latter being the coxites (gonocoxites) which form the ovipositor; *c* = cercus; *pp* = paraproct (podical plate); *sl* = suranal plate; *sp* = 8th abdominal spiracle. Roman numerals indicate terga and Arabic indicate sterna.

brane behind the 8th sternum. The latter has no structures projecting from it because, during the process of development, these have become enclosed between the two large pairs. By separating the large pairs, a minute pair of processes (those of the 8th sternum) will be seen attached beneath the dorsal pair (see Fig. 50).

The working of the parts will be described after the dissection of the female reproductive system has been outlined.

The Abdomen of the Male. Take a male specimen, lay it on its side and make a drawing of the posterior segments. Examination will show that the

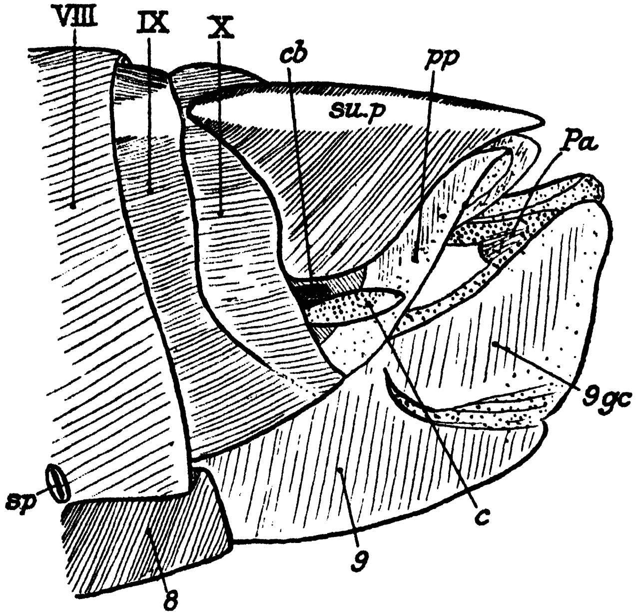

FIG. 51.—Grasshopper ♂. Side view of apex of abdomen in a state of rest.

c = cercus; *cb* = basipodite of cercus; *Pa* = the "pallium" membrane covering the gonopophyses; *pp* = paraproct (podical plate); *sp* = 8th abdominal spiracle; *su.p.* = suranal plate. Roman numerals indicate terga, Arabic numerals indicate sterna. 9 *gc* = the gonocoxite of segment 9.

first eight segments are easily recognized as complete with tergum and sternum. Behind this the partly fused terga of segments 9 and 10 can be made out, followed by a suranal plate, paraprocts and cerci, as in the female. There appear to be two sterna behind that of segment 8. The first of these is the true 9th and the 2nd is the fused coxites of the same segment forming the "subgenital plate" (or the "hypandrium" of Crampton. See *Bull. Brooklyn Ent. Soc.*, XIII, 1918). In a state of rest this plate is curved upward so that its apex fits in beneath the suranal plate and closes the end of the abdomen. If the apex is gently pressed downwards, a cavity is revealed, in the middle of which is the apex of the ædeagophore, the intromissive organ (see Fig. 51). Fig. 52 shows a dorsal view of the apex of the abdomen.

The ædeagophore is a large structure which can be projected for copulation. If it is desired to see it, remove the apex of the abdomen and boil in potash, when it will be possible to draw out the organ to its full extent by seizing the apex with a pair of fine forceps. The structure consists of a pointed ædeagus with two lateral projections representing the parameres or lateral lobes

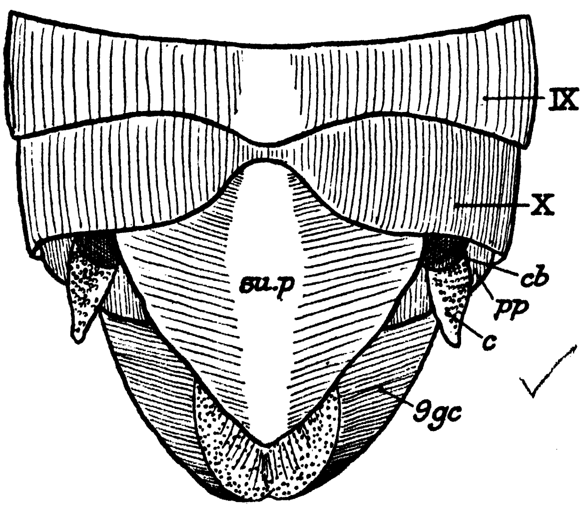

FIG. 52.—Grasshopper ♂. Dorsal view of apex of abdomen in a state of rest.

c = cercus; *cb* = basipodite of cercus; *pp* = paraproct (podical plate); *su.p* = suranal plate; 9*gc* = the gonocoxite of the 9th sternum; IX and X = 9th and 10th terga.

and, below these, a transverse chitinous plate bearing two conspicuous hooks, the pseudosternite (see reference to Walker, E. M., footnote on p. 102) (see Fig. 53).

Dissection

Use a female specimen for this part of the work as this sex is usually the larger.

Pin down the insect dorsal side up, by inserting one fine pin through the middle of the head. Spread the wings by means of pins and, if necessary, fix the legs. Carefully slit up the thoracic and abdominal segments along the

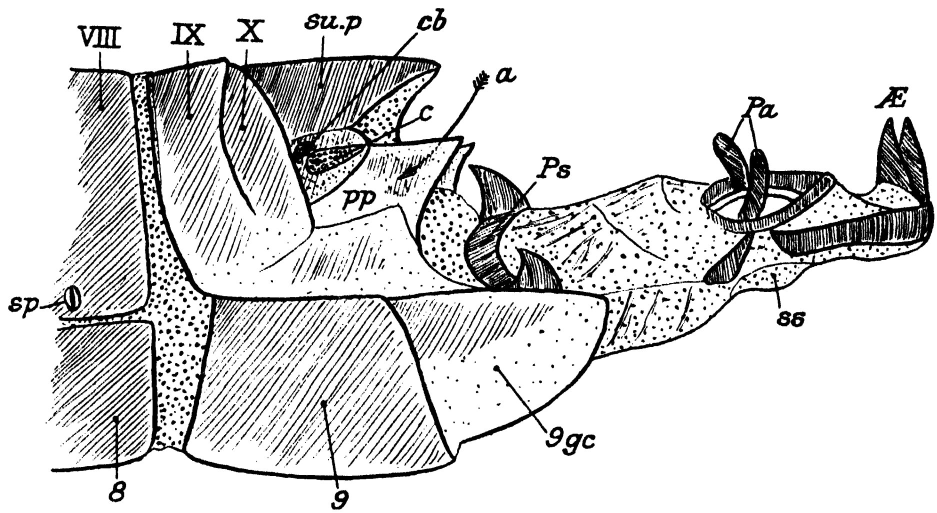

FIG. 53.—Grasshopper ♂. Lateral view of apex of abdomen, after boiling in potash, with genital armature extended.

a = anus (dotted in); *Æ* = ædeagus; *c* = cercus; *cb* = basipodite of cercus; *Pa* = parameres, sunk in an invagination; *pp.* = paraprocts (podical plates); *Ps* = pseudosternite of ædeagophore; *ss* = spermatophore sac; *sp* = 8th abdominal spiracle; *su.p.* = suranal plate. Roman numerals = terga; Arabic numerals = sterna. 9*gc* = gonacoxite.

median line from the last abdominal to the 1st thoracic, marking the 8th abdominal by means of a black pin on each side.

In the thoracic region note in the meso- and meta-thorax the longitudinal muscles lying side by side in the median line and, on each side of them, the large muscles in a more or less vertical position. The movements of these sets of muscles vary the shape of the thorax and are largely responsible for the movements of the wings.

Remove the longitudinal muscles carefully, first noting, if possible, the aorta lying between them, and then spread out the thorax and pin down on each side. In the prothorax note a pair of large air-sacs. In the abdominal region, in the median line, note the heart, the anterior end of which passes into the aorta in the metathoracic or 1st abdominal segment, lying on the pericardial

membrane. If the specimen is in a good state of preservation the alary muscles, triangular patches based on the heart and projecting out on each side, will be recognizable.

Clear away the heart and pericardial membrane and pin back the abdominal wall on each side.

While doing this, note, on each side of the 1st abdominal segment, the tympanic membrane within the chitinous tympanic ring, associated with a pair of large membranous air-sacs which meet in the middle line. (*N.B.*—These sacs are larger in the male than in the female.) Lying over the central mass will be seen, on each side, a series of air-sacs arranged down the abdomen. These arise from a large lateral tracheal trunk and project upwards. They can be easily recognized as far back as segment 8. Such air-sacs are commonly found in winged insects. As to function, their expansion displaces the blood. Thus, if the abdominal ones are expanded, the blood is forced forward and also the centre of gravity and the moving of this latter would affect up-and-down direction of flight. It has also been suggested that the thoracic air-sacs, which lie beneath the wing-bases, act as a pneumatic cushion from which the wing rebounds at the end of its down-stroke and thus gets a start for the up-stroke.

The opening up of the abdomen and removal of the heart and pericardial membrane will expose the gonadial mass. With a fine cutting needle, work carefully down so as to divide it into two; ease it away to each side and then cut it out without interfering with any of the other organs. (*N.B.*—Be very careful not to remove a mass of tissue in the anterior abdominal region, the cæca of the mid-gut.)

The Alimentary Canal. The alimentary canal is now exposed throughout its whole length from just behind the mouth to just before the anus. In the thoracic region lies the œsophagus, extending from the head to the 1st or 2nd abdominal segment. This leads into the mid-gut, the anterior part of which is surrounded by six long mesenteric or gastric cæca which lie forwards and closely adhere to the walls of the œsophagus. Gently free one of these cæca so as to see the point of entrance into the gut at the line of junction of the fore- and mid-guts. Note that there is no proventriculus (the so-called gizzard) such as is seen in the Cockroach.

The fore-gut or stomodæum is ectodermal in origin, being formed by the invagination of the outer surface, and thus it is lined with a fine layer of chitin.

The mid-gut (mesenteron, ventriculus or "stomach"), mesodermal in origin, is a straight tube occupying about four or five segments and ending in a constriction in the 5th or 6th abdominal segment, where it enters the hind-gut or proctodæum. The line of union of the mid- and hind-guts is recognized not only by the constriction but also by the fact that, in this insect, and

in many others, the malpighian tubules (fine reddish tubes adhering to the walls of the mid- and hind-guts) enter the gut at this place. (*N.B.*—The number of tubules varies considerably in different types, although where there are more than from two to six the increased number is due to branching.)

The hind-gut (proctodæum) is a straight tube leading from the mid-gut to the anus; the anus lies immediately below the suranal plate which, as already explained, may be the tergum of the 11th segment. The hind-gut shows scarcely any differentiation, there being only one slight constriction about one-third of the way from its anterior end. The part behind this might perhaps be called the rectum.

Draw a general plan of the dissection showing the alimentary canal in position and marking off the thoracic and abdominal segments. On each side of the alimentary canal, in the abdominal region, note five flat chitinous plates arising from the anterior corners of the sterna of segments 3 to 7 and lying anterior to the sterna to which they belong. The plates project upwards on each side of the gut and the trachæa to each abdominal spiracle passes out from the lateral tracheal trunk immediately behind the plate. These are endosternites or apodemes.

The Nervous System. Cut through the alimentary canal in the neck and very carefully turn it backwards, freeing the adhering tissues on its ventral side so as not to disturb them from their other attachments. Turn the gut right back to the last abdominal segment so that it is clear of the body. At the extreme front of the dissection, a pair of nerve-chords should be seen rising up from beneath a transversely-placed band of chitin, the tentorial bridge, which holds down the sub-œsophageal ganglia. Follow these nerve-chords backwards, noting the prothoracic, meso- and meta-thoracic ganglia in their respective segments, the last lying at the posterior edge of the metathorax. Fused with it are the small 1st abdominal ganglia. Posterior to this the chord and the ganglia diminish in size, but there are five other pairs, one in segment 2 and one in or about each of the segments 6, 7 and 8, the last three being larger and more easily seen. The last two or three overlie, in both sexes, a part of the reproductive system, the spermatheca in the female, the anterior end of the ductus in the male. Note the large pair of nerves extending back from the last pair of ganglia.

The Reproductive System

THE FEMALE. Take a female grasshopper, fix it down and open as before and carefully remove the heart and pericardial membrane. Note the mass of the ovaries extending from the pro- or meso-thorax almost as far back as the rectal constriction of the hind-gut. (*N.B.*—The size of, and consequently the space occupied by, the ovaries depends upon the sexual maturity of the specimen.) There are two ovaries, one on each side of the body, but, if large, they are closely adpressed and appear as one mass. Each ovary consists of a series of

egg-tubes or ovarioles and in each tube is a series of eggs, the youngest and smallest towards the anterior end of the tube. Each tube tapers anteriorly into a fine terminal thread and all the threads unite into a single ligament which is attached in the thorax. The bases of the egg-tubes of each ovary open into a large oviduct (sometimes called the "calyx") which tapers off anteriorly and, in front of the attachment of the first egg-tube, bears a short gland which may be seen, one in each side of the mesothorax just outside the apices of the anterior tubes.

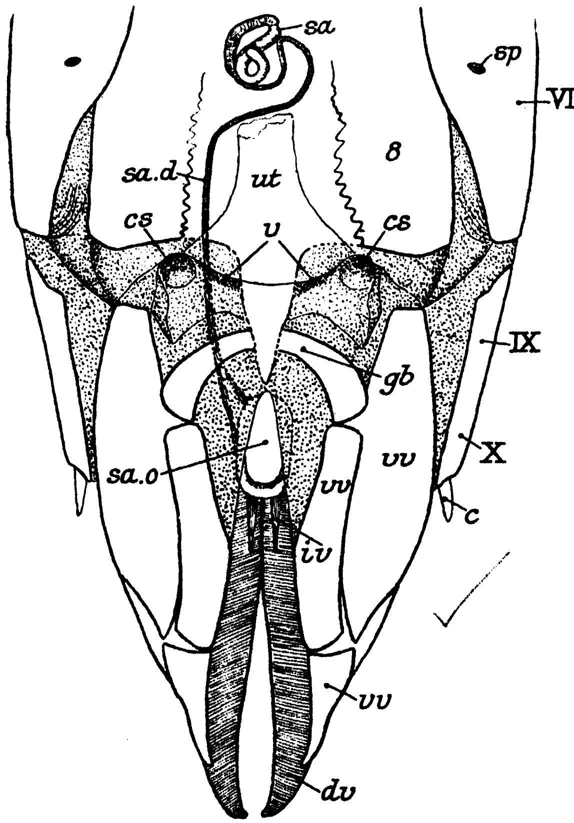

FIG. 54.—Grasshopper ♀. Ventral view of the apex of the abdomen, after boiling in potash and extending the parts.

The edge of the middle portion of the 8th sternum is shown by a dotted line and the suggestion that it has been cut out is indicated by two sinuous lines, the uterus or vagina and the vulva being the important parts. *c* = apex of cercus; *cs* = two membranous cul-de-sacs, one on each side of the vulva; *dv* = dorsal valve of ovipositor; *gb* = the gonapophytic bow; *iv* = inner valves of ovipositor which are appendages of segment 8; *sa* = spermatheca; *sa.d* = spermathecal duct; *sa.o* = opening of duct; *sp* = 8th abdominal spiracle; *v* = vulva; *vv* = ventral valve of ovipositor; VIII, IX and X = terga and 8 = sternum of abdomen.

Gently separate the right ovary and oviduct from its attachments, being careful not to damage the oviduct, and follow the latter backwards. Note that it passes down and beneath the gut at the rectal constriction. Cut through the œsophagus, as in the dissection for the nervous system, and, as before, turn the gut right back to the end of the body, being careful to leave the nerve-chord intact. Follow the right oviduct down to its point of union with the left oviduct and note the "common oviduct" or "uterus" which extends backwards. Note again the three overlying ganglia of the nerve-chord and, beneath these ganglia, the spermatheca (the receptacle which stores the spermatozoa until they are required for the fertilization of the eggs). Clear away the posterior end of the nerve-chord and note the spermathecal duct which is long and convoluted. Very carefully trace it forward and note its entry into the spermatheca and also the small nutrient gland which lies immediately posterior to the latter and communicates with the spermathecal duct.

Draw a general view of the system, ovaries and oviducts passing into the uterus and also showing the overlying spermatheca.

Special Part. Note that the spermatheca lies just behind a pair of struts projecting upwards and backwards, which are surrounded by muscles attached to their apices. These are the endosternites of the dorsal gonapophyses.

Clear away the muscle tissue round the right strut so as to free it and gently press it upwards and backwards towards the left side, bringing with it the spermatheca. This will stretch the dorsal wall of the uterus which will ultimately rupture and the whole of the gonapophyses may be separated from the body in one piece, carrying with them the spermatheca and duct intact. Turn this piece over and note the narrow longitudinal slit in the dorsal wall of the uterus, the opening of the spermathecal duct. This slit is bordered anteriorly by a chitinous strip, the "gonapophytic bow." Note the relative positions of the four gonapophyses and, in the floor of the uterus (which remains attached to the body), note the chitinous edge and the median projection which exactly fits into a space between the two ventral gonapophyses.

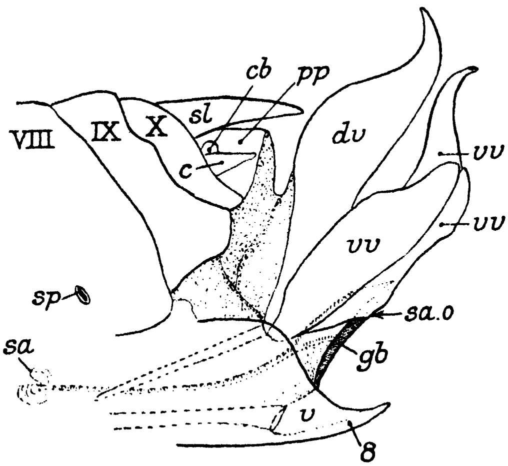

FIG. 55.—Grasshopper ♀. Armature in position for copulation.

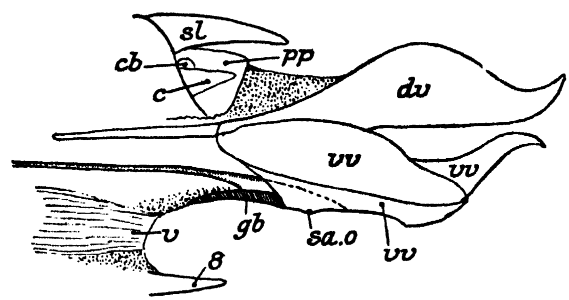

FIG. 56.—Grasshopper ♀. Armature in position for oviposition.

c = cercus; *cb* = basipodite of cercus; *dv* = dorsal valve and *vv* = ventral valve of ovipositor; *gb* = gonapophytic bow; *pp* = paraproct; *sa* = spermatheca; *sa.o* = opening of spermathecal duct; *sl* = suranal plate; *sp* = 8th abdominal spiracle; *v* = vulva; VIII, IX, X = terga; 8 = sternum.

By cutting off the abdomen and boiling it in potash, the relationship of the various parts at the apex of the body can be made out, as it is possible to extend the armature. A ventral view of the extended parts is shown in Fig. 54.

The Working of the Female Armature

(1) In copulation, the spermatozoa have to reach the opening of the spermathecal duct. To accomplish this, the four gonapophyses are raised up and the dorsal lip of the uterus is depressed. This movement depresses the gonapophytic bow which thus closes the mouth of the uterus and brings the slit-like opening of the spermathecal duct directly opposite the entrance, for the reception of the spermatozoa (Fig. 55).

(2) In egg-laying, the four gonapophyses project straight out from the abdomen so that the gonapophytic bow is now horizontal and the slit-like opening of the spermathecal duct lies just above the vulva and in such a position that every egg passing out from the oviduct must come into contact with the issuing spermatozoa (see Fig. 56).

Male Reproductive System

Take a male grasshopper, fix it down and open it, as was done in the case of the female, and remove the heart and pericardial membrane. Note the large mass of the two fused testes occupying much the same region as the ovaries in the female. Open the testicular capsule and note that the testes consist of numerous follicles, all of which lie so as to open into a duct, the vas deferens, lying immediately beneath each testis. The two vasa deferentia can be traced backwards along the sides of the gut to the 8th or 9th segment. Gently separate the testes from the gut, without breaking the vasa deferentia, and turn the whole mass over to the left side of the body. Now cut through the gut in the region of the rectal constriction and turn the parts forwards and back respectively, so as to clear it from the body. Follow the vasa deferentia and note that, in the 8th or 9th segment, they turn downward and forward and that each enters among a mass of long thick tubes which lie forward along each side of the body as far as the 3rd or 4th abdominal segment. These tubes constitute the two vesiculæ seminales and the tubes belonging to each converge where the vas deferens meets them and they and the vasa deferentia unite with the anterior end of the ductus ejaculatorius, which lies straight backwards and opens between the dorsal and ventral gonapophyses. Immediately opposite to the point on each side where the vas deferens enters the ductus is the entrance of an "accessory gland," an opaque white tube which lies forward among the tubes of the seminal vesicles and is greatly convoluted.

Draw the male reproductive system, the paired testes in their sac, the vasa deferentia, vesiculæ seminales, accessory gland and ductus ejaculatorius.

The structure of the male genital armature is highly complex, too complex for examination in detail in this course, and the interpretations as to the homologies are by no means clear. A diagrammatic figure is given (see p. 105) and for detailed discussion, see Walker, E. M., l.c.

THERE are six principal longitudinal veins in the insect wing: (1) The Costa (C), running along the anterior border, normally without any spurs or branches. (2) The Subcosta (Sc), which may divide into two. (3) The Radius (R), which —usually about half-way out in the wing—divides into two, the lower branch, Radial Sector (RS), dividing again and each branch again producing two, the radial system thus being 5-branched. (4) The Media (M), which divides into two and each branch divides once again, the system thus being 4-branched though, according to Comstock's nomenclature, M4 is usually absent. (5) The Cubitus (Cu), which divides into two. (6) The Anal group of which one, two

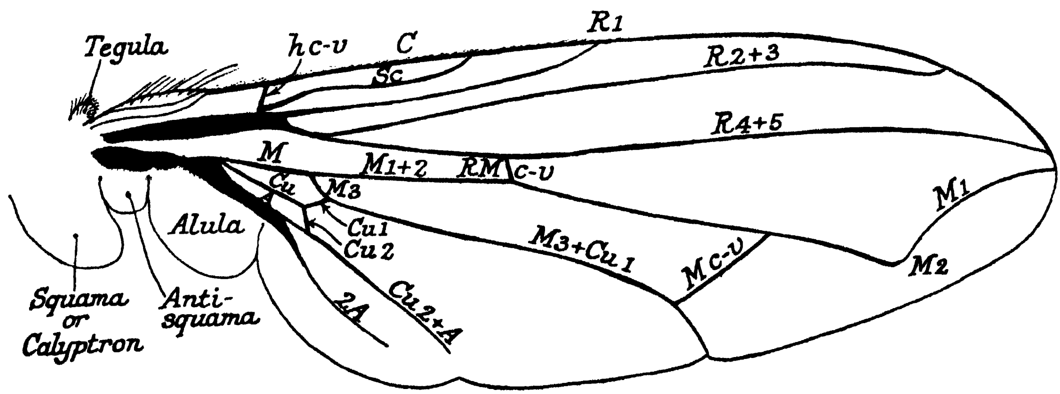

FIG. 57.—Wing of the Blow-fly (Calliphora erythrocephala).

or more may be present. Tillyard's nomenclature differs in certain points from that of Comstock, and although it is preferable to identify correctly the different veins I am not satisfied that Tillyard's method is altogether more correct than Comstock's and I have therefore retained the older system.

Type I. Diptera. Example, The Blowfly (see Fig. 57).

Remove a wing, taking care to get the whole of it. Mount in glycerine or, if you prefer it, dehydrate, clear and mount in balsam. Examine the venation, noting first the Radio-Medial cross-vein (R-M c-v), more or less in the middle of the wing, a short vertical vein. (*N.B.*—In the wings of Diptera, always find this cross-vein first.)

This c-v decides the identity of the Media. Trace the Media back towards the base and note that a branch descends and joins another longitudinal vein. The descending branch is Media 3 (M3) and the vein it joins is Cubitus 1 (Cu1)

of Comstock. (*N.B.*—In Diptera, M3 always leaves M1 + 2 nearer the base of the wing than the R-M c-v, but the position of its departure varies in different families, and is of systematic importance.)

M3 does not always fuse with Cu, but may become a longitudinal vein on its own account and Cu then always turns upward at an angle and (1) fuses with

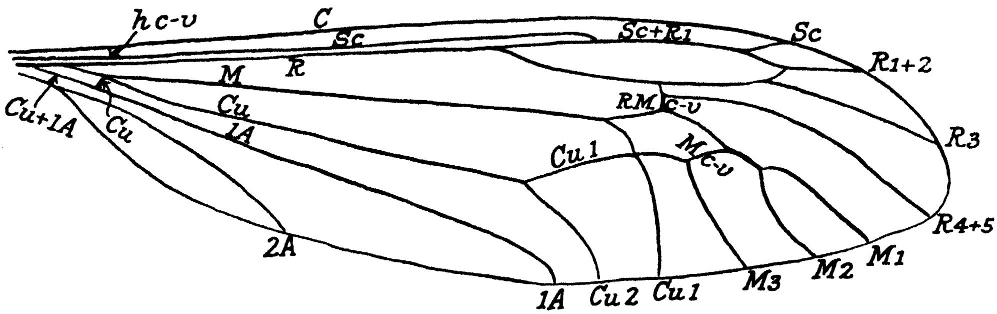

FIG. 58.—Wing of Tipula sp.

M3 and then breaks away again or (2) bends down again and becomes a longitudinal vein without joining M3 but is connected with it by a cross-vein, the MCu c-v. These are points of systematic importance.

Trace Cu back to near the base of the wing and note Cu2 descending and joining A1.

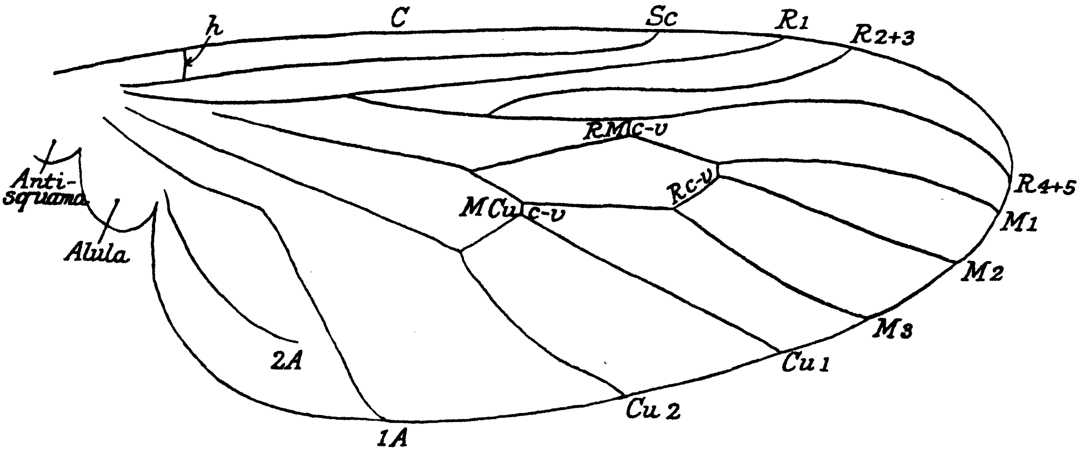

FIG. 59.—Wing of Rhyphus.

If time permits, mount the wings of other flies and draw the venation and name the veins. Otherwise, examine slides of the wings of various families, including some or all of the following: Tipulidæ, Culicidæ, Rhyphidæ, Tabanidæ, Leptidæ, Asilidæ, Bombyliidæ, Therevidæ, Empidæ, Syrphidæ, Conopidæ and various Muscinæ (see Figs. 58 and 59).

Type II. Hymenoptera. Example, The Wasp (see Figs. 60 and 60*a*).

Remove and mount the two wings from one side and examine the venation, first of the fore-wing. The large vein leaving the base at or near the anterior margin and immediately behind the Costa is a compound vein consisting of Subcosta, Radius and Media. At the node (stigma), or just before it, a branch runs off below towards the base of the wing and joins another main vein coming out from the base. This latter is the Cubitus and the branch, in the more primitive Hymenoptera, e.g. Tenthredinidæ, is the medio-cubital cross-vein. In the

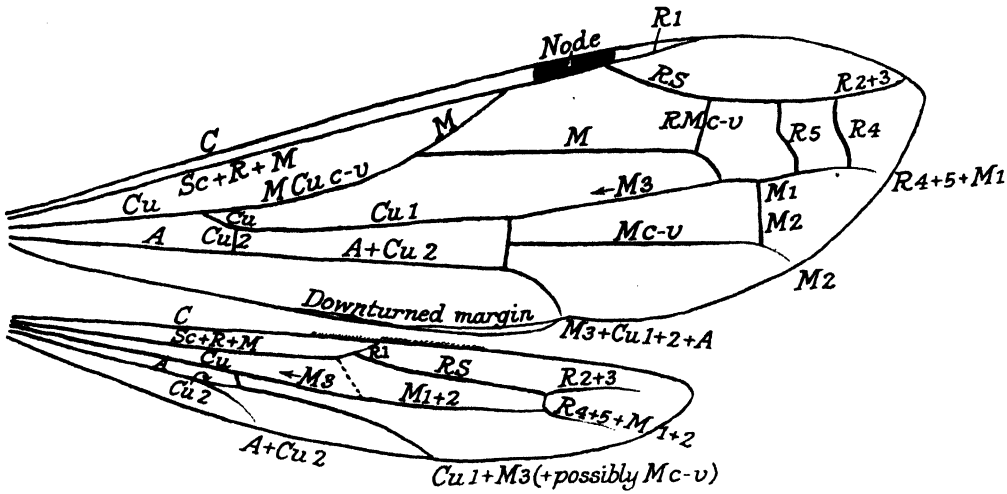

FIG. 60.—Wings of Wasp.

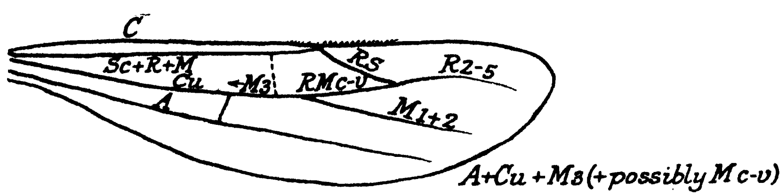

FIG. 60*a*.—Hind wing of Bombus.

higher forms, however, the Media slips down this a short distance and then turns sharply out again so that the c-v in these forms is an "arculus," i.e. a vein composed partly of a main vein and partly of a c-v.

Follow the Media outwards and note that it receives three c-vs from the Radial-Sector, which leaves the Radius just beyond the node. The first of these c-vs is the radio-medial, while the others are the fifth and fourth branches of the Radius. Between the points where the radio-medial c-v and R5 join the Media, a vein runs off the lower side towards the base of the wing. This unites with the Cubitus 1 and is Media 3 and, in most of the higher Hymenoptera, starts out from the main Media in the wrong direction, i.e. towards the base of

the wing. Media 3 and Cubitus 1 run out to the posterior margin of the wing, uniting first with the Anal vein, which has previously received the short Cu2.

Note a longitudinal vein below M3 and more or less parallel with it. This is the median c-v and always appears as a longitudinal vein in the Hymenoptera. In the wasp, and in many other Hymenoptera, Media 2 exists as a descending vein at the other end of the median c-v, but is often absent. Thus the keys to the interpretation of the fore-wing are the medio-cubital c-v, the base of the Media and the median c-v.

In the hind-wing, the venation is easily understood if a careful comparison is made with that of the fore-wing. The Media runs out in a compound vein, but it is absent from the membrane where it should leave that vein. The Cubitus, to all appearance, runs straight out through the wing, but comparison with the fore-wing shows that, beyond a point where a vein drops from it, more or less at right angles, it becomes first M3 and then M1 + 2. We may therefore assume that it is so composed in the hind-wing and a study of a Tenthredinid Sawfly wing makes this interpretation more probably correct than that given by Comstock or by Tillyard.

An examination of a hind-wing of a Bombus (see Fig. 60*a*) shows that what appears to be the radio-medial c-v exists, and we may either regard the c-v between the Radial-Sector and Media 1 + 2 in the wasp's wing as being the same but as having moved farther out in the wing or as equivalent to R4 in the fore-wing.

If time permits, mount the wings of other Hymenoptera, draw the venation and name the veins. Otherwise, examine slides of the wings of various families, including some or all of the following: Tenthredinidæ, Siricidæ, Ichneumonidæ, Braconidæ, Evaniidæ, Chrysididæ, Crabronidæ, Eumenidæ, Andrenidæ, Apidæ. The venation varies within the families and a study of a few species, say of Tenthredinids, Andrenids and Apids, will be found very useful.

Type III. Lepidoptera. Example, the "Yellow-Underwing" or other Noctuid Moth (see Fig. 61).

Because of the scales covering both sides of the wings of Butterflies and Moths, the wings require special preparation before it is possible to examine the venation. The scales can be removed to some extent by very careful brushing with a fine brush dipped in acid alcohol, or preferably in "eau-de-javelle," [1] which gives much better results.

Examine the venation of the fore-wing, noting first the large "cell" at the base, the Radial or Discal cell. This gap in the venation is due to the absence of the basal part of the Median vein which has disappeared in all but the more primitive moths, e.g. Hepialidæ, Cossidæ, etc. The vein bounding the lower side of the cell is the Cubitus and the first branch it gives off, after starting from

[1] Two ounces of chloride of lime, four ounces of carbonate of potash or soda and two pints of water.

the base of the wing, is Cubitus 2 of Comstock. The next branch is Cubitus 1, and the continuation outwards is the medio-cubital c-v which connects with Media 3. Above M3 are M2 and then M1. The position of M2, whether it is nearer to M1 than to M3 or otherwise, is an important character in separating certain families of moths. The Radius, as usual, consists of five branches, R1 and RS being usually easy to make out but, in many Lepidoptera, R2, R3, R4

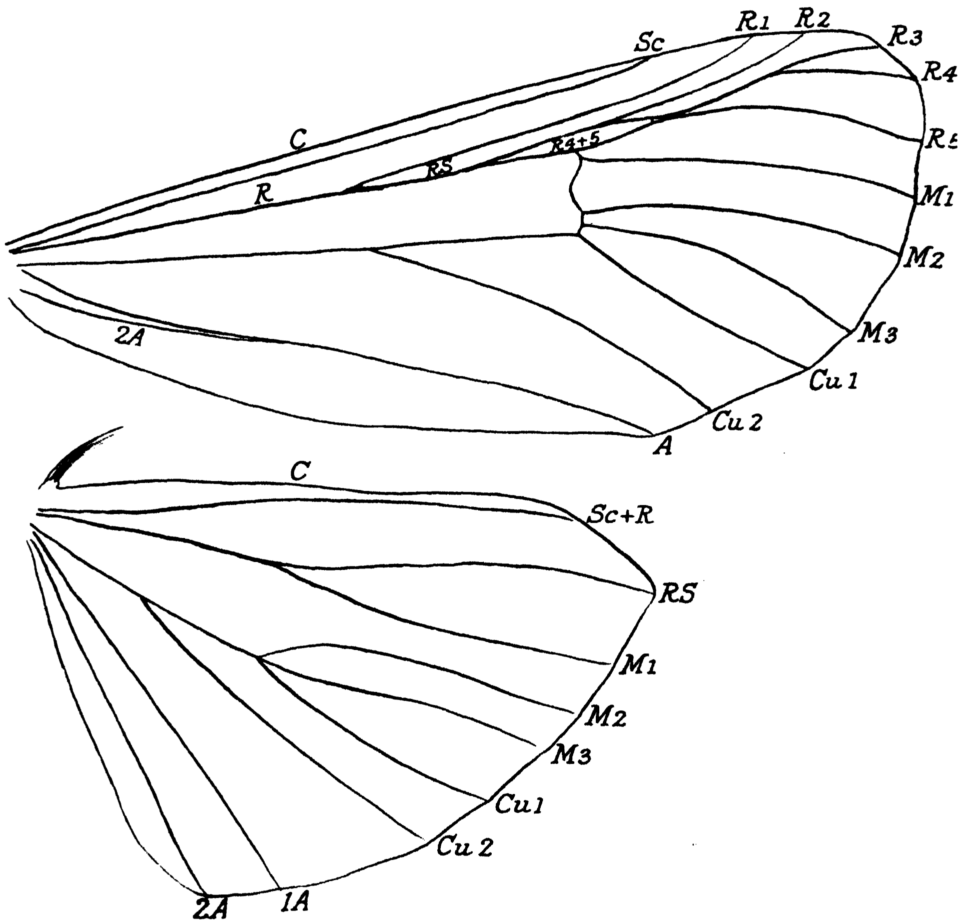

FIG. 61.—Wings of Noctuid Moth, Plusia sp.

and R5 make various fusions among themselves and are frequently difficult to determine.

The cell and the Cubitus vein are the clue to the Lepidopterous fore-wing and should always be found first.

(*N.B.*—Tillyard (1919) suggests that Cu1 and Cu2 referred to are really both branches of Cu1 and that the first Anal vein of Comstock is the real Cu2.)

Examine the venation of the hind-wing, finding the Cubitus in the same way as in the fore-wing. The three veins above Cu 1 are the branches of the Media and the next vein above is the undivided Radial-Sector. The uppermost vein is Subcosta and Radius 1 fused together. The evidence for this is to be found in the hind-wing of the Cossidæ, e.g. *Cossus ligniperda*, the Goat Moth.

All the butterflies and those moths which show this marked difference in venation between the fore- and hind-wings belong to the sub-Order Hetero-

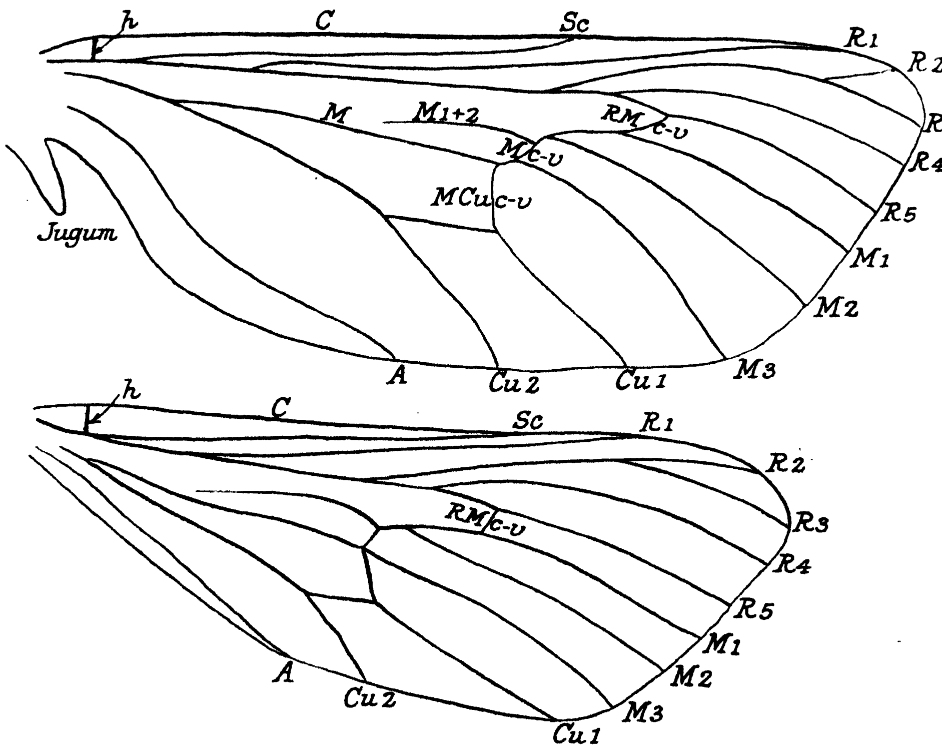

FIG. 62.—Wings of Hepialus sp.

neura, while those few moths in which the venation of the fore- and hind-wings is similar, belong to the more primitive sub-Order Homoneura, which includes the Micropterygidæ, Hepialidæ and a few related families (see Fig. 62). If time permits, mount the wings of other specimens, draw the venation and name the veins. Otherwise, examine slides of the wings of various families including some or all of the following: Hepialidæ, Ægeriidæ (Sesiidæ), Cossidæ, Zygænidæ, Lasiocampidæ, Hesperiidæ, Papilionidæ, Pieridæ, Nemeobiidæ (Erycinidæ), Lycænidæ, Nymphalidæ, Bombycidæ, Geometridæ, Sphingidæ, Arctiidæ. It will also be found useful to note differences within families, e.g. Nymphalidæ, Geometridæ, Noctuidæ, etc.

The Nomenclature of the Cells of the Wing, i.e. of the Areas bounded by the Veins

(1) The cell takes the name of the vein above it. Thus, a cell below M will be M cell; below M1 will be M1 cell.

(2) If there is more than one cell below a vein, the one nearest to the base of the wing is the "first," the next is the "second," and so on. Thus, 1st M cell, 2nd M cell; 1st M1 cell, etc.

(3) Where a vein is compound, the cell below it is the cell of the lowest of the veins composing the compound vein. Thus, in the Hymenopterous wing, the cell below Sc-R-M is M cell.

III. THE EXTERNAL MORPHOLOGY OF INSECT TYPES THE RHYNCHOTA (HEMIPTERA)

THE Rhynchota are divided into two sub-orders, Heteroptera and Homoptera.

TYPE 1. PENTATOMID BUG: as an example of Heteroptera, e.g. *Piezodorus lituratus*, or *Pentatoma rufipes*.

Head. Examine the head, dorsal view, and note the two ocelli on the posterior region of epicranium.

The absence of sutures is a characteristic feature, the fronto-clypeal region being a continuation forward of the epicranial region. The narrow fronto-clypeus is clearly marked off from two large lateral "adfrontal" regions, the genæ, which are angulated laterally and continue beneath the head, where sutures separate them from the gular region.

There is no division between frons and clypeus; the anterior end of the fronto-clypeus continues a short distance on to the ventral side where a slight depression marks its union with the labrum.

Note how the gular sclerite forms a ridge on each side of the reflexed base of the labium and how these ridges rise up on each side at the base anteriorly so as to come into contact with the sides of the labrum. The position of the antennæ varies in different Heteroptera, but in the Pentatomids they are inserted each on a small tubercle, the "antenniferous tubercle," immediately anterior to each eye and ventral to the lateral ridge of the "adfrontals."

Examine the rostrum (labium) in side view and note, first, that it is attached near the front of the underside of the head and that it quite obviously has nothing to do with the thorax. This is the case in all Heteroptera and is important because, in the Homoptera, a side view of the insect gives the impression that the rostrum comes off from between the front legs. This is, therefore, a character which distinguishes the Heteroptera from the Homoptera.

Now note that it is composed of four segments. (*N.B.*—The number of segments varies in different families, being three in some Heteroptera (e.g. Cimicidæ, Reduviidæ, etc.) and in some Homoptera (e.g. Cicadidæ, etc.) and two or one in some Homoptera (e.g. Coccidæ).)

1. Draw a dorsal and a lateral view of the head.

Thorax. Dorsal view. The Prothorax is represented by a large pronotum, behind which is the triangular scutellum of the mesonotum (always well marked in the Pentatomids), flanked on each side by the coriaceous basal parts of

the "hemi-elytra." On each side of the hemi-elytra, the flattened margins of the abdomen are visible. These are known as the "connexivum."

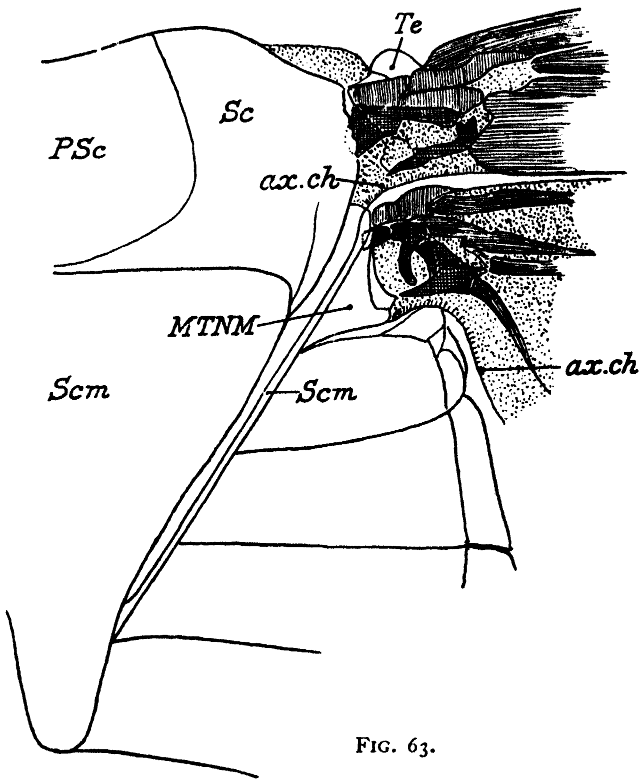

FIG. 63.

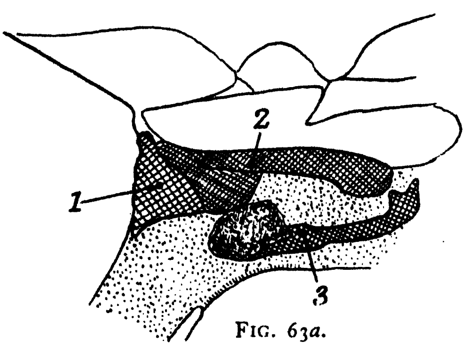

FIG. 63*a*.

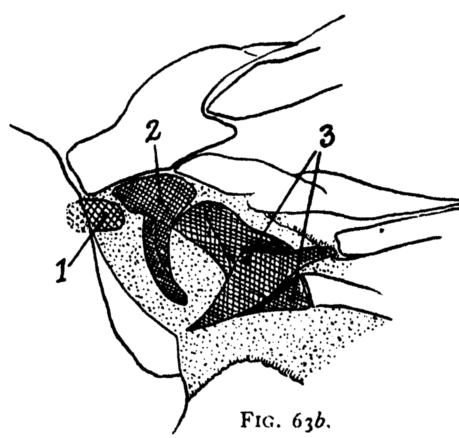

FIG. 63*b*.

FIGS. 63, 63*a* and 63*b*.—Pentatomid Bug. Dorsal view of mesothorax and what is visible of metathorax (*MTNM*) and wing attachments.

ax.ch = axillary chord; *PSc* = prescutum; *Sc* = scutum; *Scm* = scutellum; *Te* = tegula.

Figs. 63*a* and 63*b* show the axillary sclerites of meso- and meta-thorax, after boiling in potash. In *a*, the part of sclerite 3 which dips down to the ventral surface of the wing, is shown.

2. Draw a general view of the dorsal aspect.

Insert a needle or scalpel beneath the posterior edge of the pronotum and gently raise it up until the whole prothorax and head break off from the rest of the body. This exposes to view the whole mesonotum and the main sclerites are easily recognized; the prescutum, bounded on each side by the scutum and posteriorly by the scutellum.

Spread the hemi-elytron and wing on one side and see the anterior lateral projection of the meso-scutellum which carries the axillary chord (see Fig. 63).

3. Draw the mesonotum.

Remove and examine the hemi-elytron.

Note that the main basal part, the "corium," is bounded anteriorly by a partially separated "embolium" and posteriorly by a completely separated "clavus." There is no "cuneus."

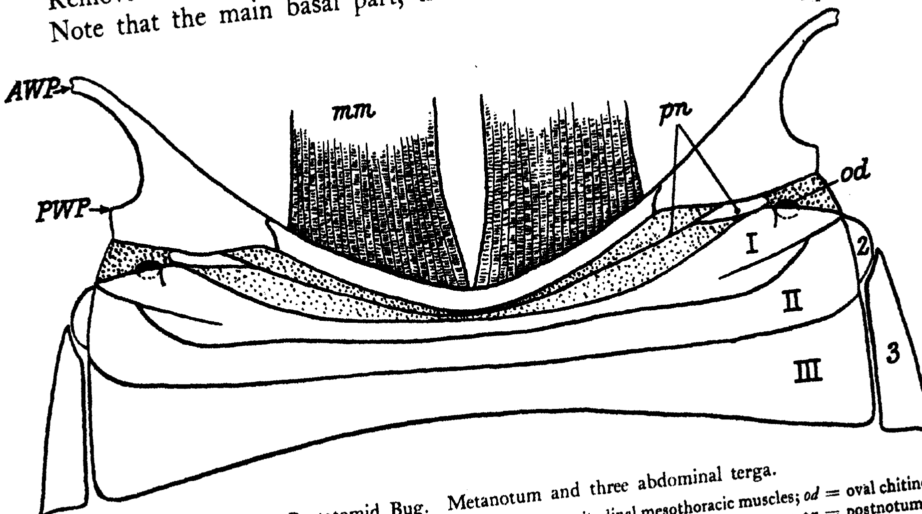

FIG. 64.—Pentatomid Bug. Metanotum and three abdominal terga. *AWP* and *PWP* = ant. and post.-notal wing processes; *mm* = the large longitudinal mesothoracic muscles; *od* = oval chitinous sclerite in the position of the 1st abdominal spiracle of those Heteropterous bugs in which it occurs; *pn* = postnotum.

The apical part is the "membrane."

4. Draw the hemi-elytron.

Remove the other hemi-elytron and, placing the point of a scalpel beneath the apex of the scutellum, gently force it upward until it breaks off, exposing the metanotum and the mesothoracic muscles anterior to this. (Note that part of the metanotum will probably remain attached to the underside of the scutellum. If so, it is part of the prescutum.) (See Fig. 64).

The metanotum is very narrow, the main part of it being the prescutum in the middle and the scuta carrying the wings at the sides.

The scutellum is very narrow and is most easily traced in the sides, where it extends into the axillary chords.

Immediately behind the scutellum is the narrow "post-notum" which enlarges laterally, becomes triangular and is fused with the metathoracic epimera.

Thorax. Ventral view. The prothorax shows a large overlap of the notum at the sides, the coxæ sunk in pits covered in anteriorly by flaps of the sternum and posteriorly by flaps of the pleura. The pleura are incompletely marked off from the overlap of the tergum and the pleural suture is recognizable at the point of attachment of the coxa but quickly fades out.

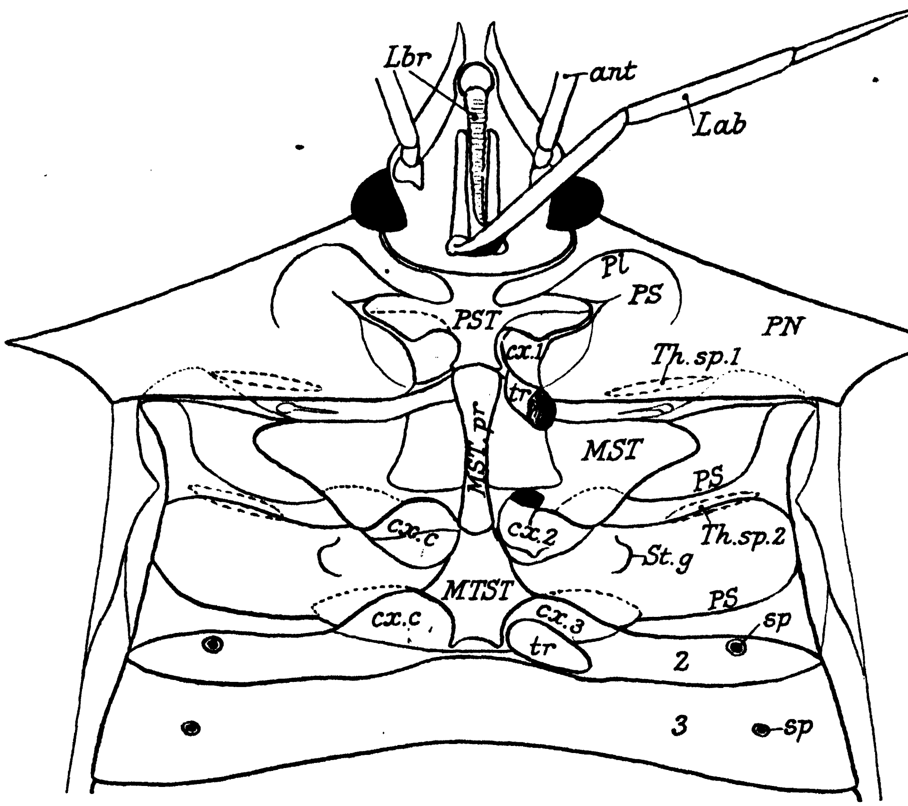

FIG. 65.—Pentatomid Bug. Ventral view of head, thorax and ant. abdominal segments. *ant* = base of antenna; *cx* = coxa; *cx.c* = coxal cavity; *Lab* = labium; *Lbr* = labrum; *MST* = mesosternum; *MST.pr* = mesosternal process; *MTST* = metasternum; *Pl* = pleuron; *PN* = pronotum; *PS* = pleural suture; *PST* = prosternum; *sp* = spiracle; *St.g* = opening of stink gland; *Th.sp* = thoracic spiracle; *tr* = trochanter; 2 and 3 = abdominal sterna.

The mesothorax shows a narrow medial sternal ridge and broad sternal plates projecting laterally. The pleura are distinct and the pleural suture, although difficult to see, is traceable according to the usual rule (see Fig. 65). The metathorax shows a small metasternal plate, large episterna separated from narrow epimera by pleural sutures, difficult to see, as in the mesothorax.

There are two pairs of large slit-like spiracles belonging to the thorax;

these are to be found on the ventral side, one pair in the membrane between pro- and meso-thorax and the other between the meso- and meta-thorax. Both pairs require careful searching for. In the episterna of the metathorax note the openings of the "stink-glands."

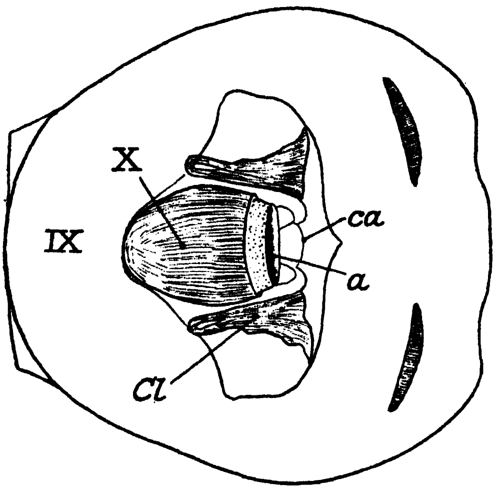

FIG. 66.—Pentatomid Bug ♂ (Species A). Dorsal view of pygophor in a state of rest.

a = anus; *ca* = cavity containing ædeagus; *Cl* = clasper; IX and X = segment 9 and 10th tergum.

Lay the insect upon its back and make a drawing of the thorax, showing the parts mentioned.

Abdomen. The 1st abdominal tergum is closely fused with the post-notum of the metathorax, so that there is considerable difficulty, except at the sides, in distinguishing the boundaries between them. The 1st sternum is absent or membranous but, bearing this in mind, ten abdominal segments exist in both sexes. The 2nd sternum is narrow, especially in the middle region, but it can be determined by the spiracle on each side of it. Behind this sternum six others with spiracles can be seen in the female but only five in the male because, under normal conditions, the true 8th segment is telescoped within the 7th. In the Pentatomids, the 1st spiracle

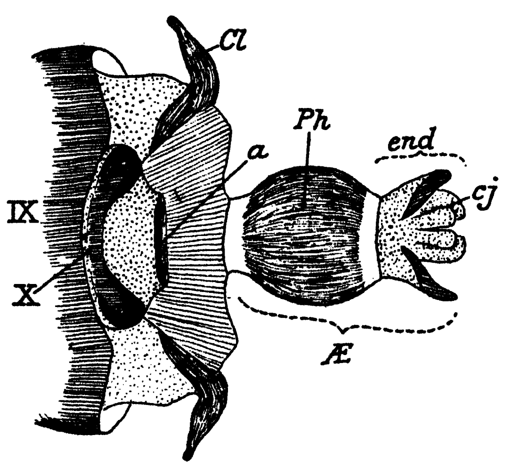

FIG. 67.—Pentatomid Bug ♂ (Species A). Dorsal view of pygophor with the parts extended after boiling in potash.

a = anus; *Æ* = ædeagus, its parts being endosoma (*end*) and conjunctiva (*cj*) of the endosoma and phallosoma (*Ph*); *Cl* = clasper; IX = pygophor (segment 9) and X = 10th tergum.

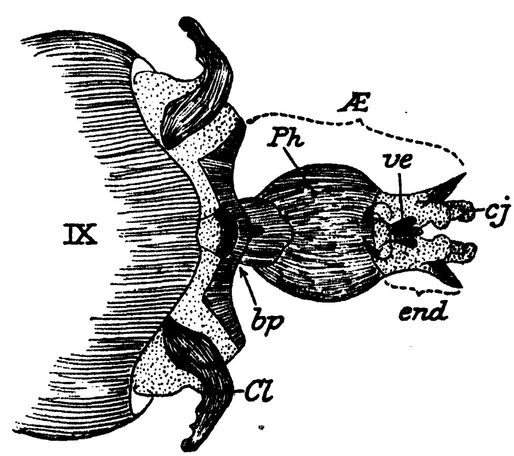

FIG. 68.—Pentatomid Bug ♂ (Species A). Ventral view of pygophor with parts extended after boiling in potash.

bp = basal piece of ædeagus. Otherwise lettering as in Fig. 67.

is absent, but it is present in some Heteroptera, e.g. Dysdercus (Pyrrhocoridæ). In some Pentatomids, its position is marked by a small dark oval of chitin. (See Fig. 64.)

In the Male, segment 8 is small and segment 9, known to systematists

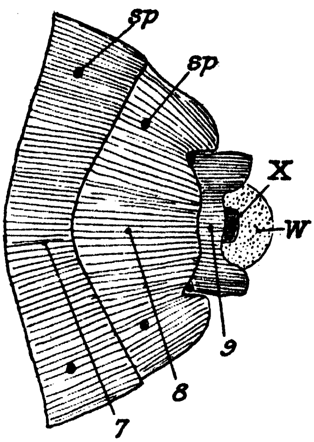

FIG. 69.—Pentatomid Bug ♂ (Species B). Ventral view of posterior abdominal segments in a state of rest.

sp = spiracle; *W* = apex of wing; *X* = 10th tergum bent over and covering the cavity containing armature; 7, 8, and 9 = sterna.

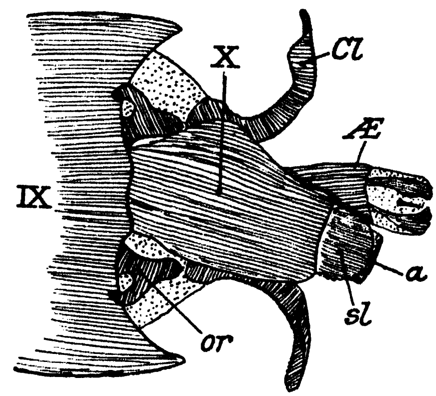

FIG. 70.—Pentatomid Bug ♂ (Species B.) Dorsal view of apex of abdomen, extended after boiling in potash.

a = anus; *Æ* = ædeagus; *Cl* = clasper; *or* = "ornament"; *sl* = suranal plate; IX = 9th segment (pygophor); X = 10th tergum.

as the "pygophor," is capsular in form, varies greatly in shape in different species and the shape is of systematic importance. The 9th encloses a small 10th

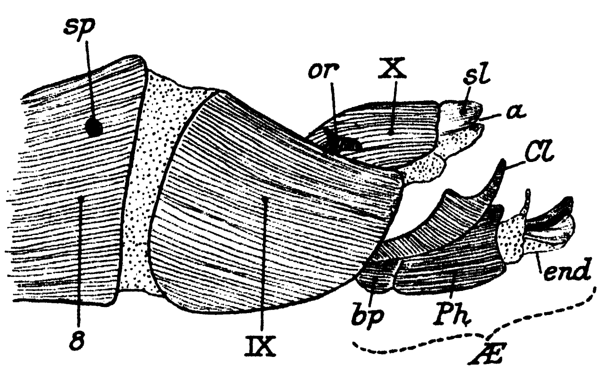

FIG. 71.—Pentatomid Bug ♂ (Species B). Lateral view of apex of abdomen, extended after boiling in potash.

a = anus; *Æ* = ædeagus (*bp* = basal piece; *end* = endosoma; *Ph* = phallosoma); *Cl* = clasper; *or* = "ornament" at the side of the base of the 10th segment; *sl* = suranal plate; 8 = 8th sternum; IX = 9th segment (pygophor); X = 10th tergum.

segment and a highly complex genital armature which, however, consists only of an ædeagus, a basal piece (usually horse-shoe-shaped), and two lateral "claspers," the form of which is used for separating the species in various genera.

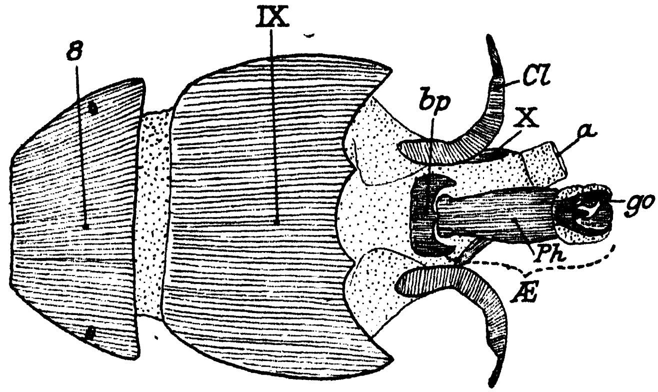

FIG. 72.—Pentatomid Bug ♂ (Species B). Ventral view of apex of abdomen, extended after boiling in potash. *a* = anus; *Æ* = ædeagus (*bp* = basal piece; *Ph* = phallosoma); *Cl* = clasper; *go* = gonopore; 8 = 8th sternum; IX = 9th segment (pygophor); X = 10th tergum.

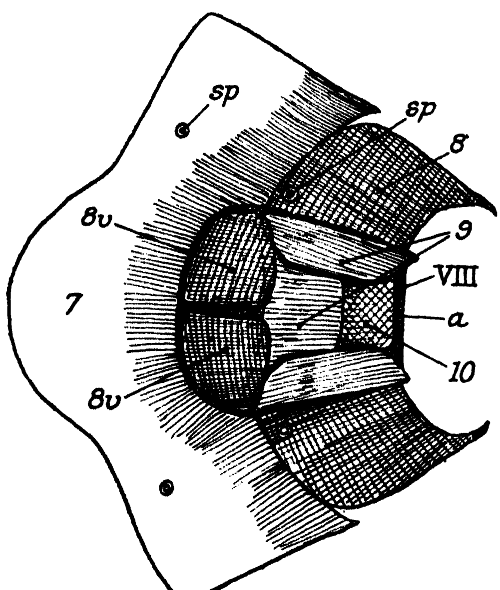

FIG. 73.—Pentatomid Bug ♀. Ventral view of apex of abdomen in a state of rest. *a* = anus; *sp* = spiracle; VIII = edge of 8th tergum; 7 = 7th sternum; 8 = 8th sternum; 8*v* = "valves"; 9 and 10 = 9th and 10th sterna.

The ædeagus is divisible into an apical membranous "conjunctiva," ventral to which is a chitinous "vesica," in which is the gonopore. These two parts, forming the "endosoma," are borne upon a chitinized tubular part, the "phallosoma," below which is the ventral basal piece with the arms of the horse-shoe projecting dorsally. (*N.B.*—The ædeagus is not always differentiated into vesica, conjunctiva and phallosoma.) (See Figs. 66–72.)

The two claspers are attached in the membrane in the end of segment 9, on each side and at the base of the ædeagus.[1]

Extract the 9th abdominal segment, boil in potash and extend the ædeagus and make drawings from above and below and name the parts.

In the Female, segments 9 and 10 are telescoped into segment 8, which

[1] Pruthi (*Trans. Ent. Soc.*, 1925, p. 133) describes these claspers as parameres, presumably regarding them as homologues of the lateral lobes of Coleoptera, but, if they were such, their attachment would be at the base of the ædeagus, above the basal piece, whereas the whole ædeagus, with its basal piece, can be drawn out to its full extent without the claspers moving from their position and without any rupture of membrane. It seems more probable that these claspers are the coxites of the 9th segment (see Figs. 68 and 72).

is normally the last abdominal segment visible from above. In a ventral view, the 7th sternum (6th visible owing to the absence of the 1st) is the last to extend unbroken across the abdomen. The 8th follows and encloses the 9th and 10th sterna. The 8th itself is divided into two large lateral portions, bearing the spiracles, and a pair of small inner plates or valves. Posterior to these valves is the 9th sternum consisting of a median and two lateral lobes, and a small 10th sternum behind the median lobe of the 9th. Although there is considerable variation in the form of these posterior sternal plates, they have, so far, not been used for systematic purposes. (See Fig. 73.)

The two median valves of sternum 8 enclose a cavity, within which is the vulva and the ovipositor, so far as it exists in the Pentatomid Bug. (See Fig. 74.)

Draw a ventral view of the posterior segments of the abdomen of the female.

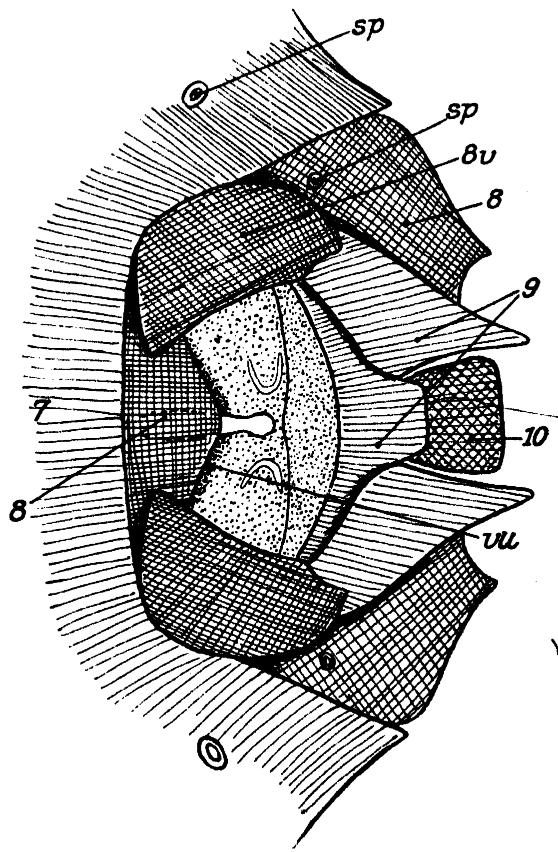

FIG. 74.—Pentatomid Bug ♀. Ventral view of apex of abdomen with the "valves" of sternum 8 separated, exposing the cavity in which is the vulva (*vu*) and the only signs of an ovipositor found in the Pentatomid.

Lettering as in Fig. 73. A specimen belonging to a different species from that shown in Fig. 73 has been used for this Fig. Note the different shape of the 8th sternum and of the lateral lobes of the 9th.

TYPE 2. CICADID BUG: as an example of the Homoptera.

Head. Note that the "face" is anterior and declivous, not dorsal, as in the Heteropterous bug.

Examine the face and note the well-marked, transversely-grooved fronto-clypeus and the large labrum below it with a fine tapering apex, the latter sometimes called the "epipharynx." On each side of the fronto-clypeus is the adfrontal region, the "lores," "lorum" or "lora" of systematists.[1]

[1] In the mouth-parts of Hymenoptera, the V-shaped strut connecting the base of the submentum with the maxillæ is called the lorum or lora. The fact that entomologists are not agreed as to the name in either case is evidence of the vague way in which entomological nomenclature has been built up, mainly by amateurs.

Note the three ocelli on the vertex, characteristic of the Cicadidæ, other Homoptera having only two. The gular sclerite, owing to the form and attachment of the Homopterous head, is absent. On the lateral anterior portion of the face and on each side of the fronto-clypeus is the "frontal ridge," beneath which is attached the antenna in a small fovea.

Thorax. Dorsal view. The main parts of the thorax, visible from above, are the broad pronotum and the large mesonotum, a part of which is concealed beneath the posterior edge of the pronotum.

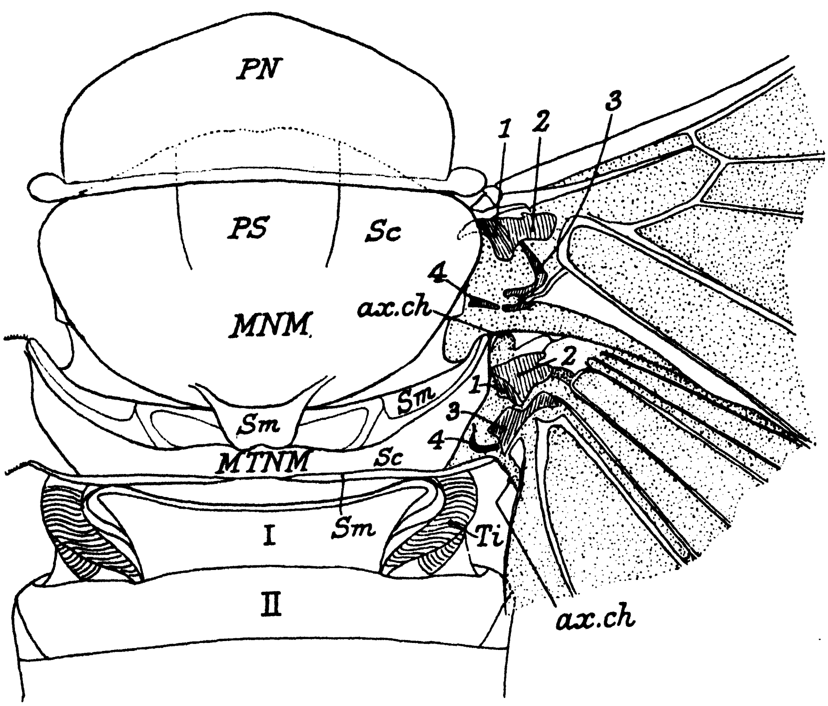

FIG. 75.—Cicada ♂. Dorsal view of thorax with wing attachments and anterior abdominal segments. *ax.ch* = axillary chord; *PN* = pronotum; *PS* = prescutum; *MNM* = mesonotum; *MTNM* = metanotum; *Sc* = scutum; *Sm* = scutellum; *Ti* = timbale or "drum"; 1 to 4 = axillary sclerites; I, II = terga of abdominal segments.

In the mesonotum, note the incompletely separated prescutal area marked off laterally by two sutures but not separated medianly from the main part of the segment, the scutum. At the posterior and postero-lateral margins of the scutum is the scutellum, raised in the middle and extending forwards into two ridges, one on each side.

Spread out a wing and notice that the scutellar ridge continues into the posterior edge of the fore-wing as the axillary chord. Just inside the axillary chord, in the axillary membrane, note the posterior (4th) axillary sclerite. The other three sclerites are possibly recognizable, but Numbers 1 and 2 are fused

together and they and Number 3 are fused with the bases of the wing-veins (see Fig. 75).

The metanotum is, in some species, only visible at the sides, in the dorsal view, unless the thorax is separated from the abdomen, but, in other species, it can be seen as a narrow band across the middle, immediately behind the meso-scutellum. Followed to the sides it spreads out into a broader piece which ends just above the insertion of the posterior wing, the axillary chord of which runs out from the scutellum as usual. On its posterior margin, the metanotum carries the ridged postnotum, which will be better seen in the side view.

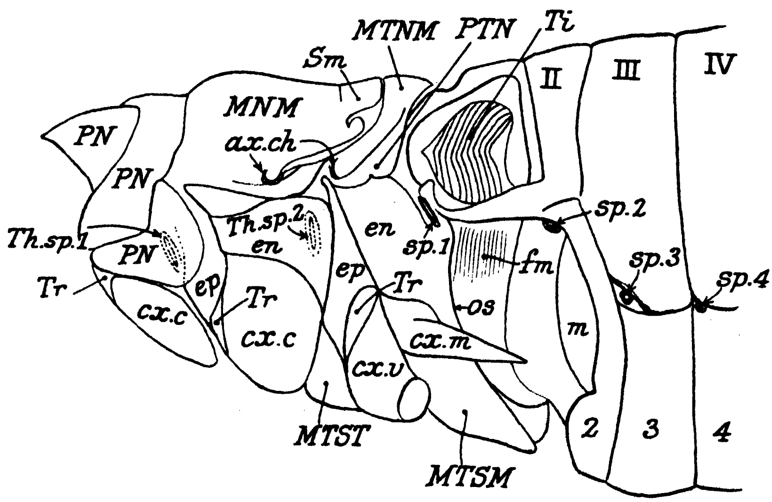

FIG. 76.—Cicada ♂. Side view of thorax and ant. abdominal segments. Operculum removed (*os* = the line of its attachment) to expose the mirror (*m*) and the folded membrane (*fm*) and the second abdominal spiracle in the cavity in which they lie.

ax.ch = axillary chord; *cx.c* = coxal cavity; *cx.m* = coxa meron, extended into a meracanthus; *cx.v* = coxa vera; *en* and *ep* = episternum and epimeron; *MNM* = mesonotum; *MTNM* = metanotum; *MTST* = metasternum; *MTSM* = metasternellum; *PN* = pronotum; *PTN* = postnotum; *sp* = abdominal spiracle; *Th.sp* = thoracic spiracle; *Tr* = trochantin.

Thorax. Side view. The pleural region of the prothorax is greatly reduced,[1] most of the side being taken up by the large coxal cavity. What there is, lies beneath the downwardly-projecting lateral margin of the pronotum. The triangular trochantin is recognizable anterior to and dorsal to the coxal cavity.

Note the membranous attachment of the base of the labium (rostrum) to the prosternum. Beneath the lateral lobe of the pronotum and behind the pleuron is the peritreme bearing the 1st thoracic spiracle. The mesothorax has a well-marked pleural region.

First determine the pleural suture in the usual way and note the episternum in front of it, bounded ventrally by a part of the mesosternum and by a triangular trochantin. Behind the pleural suture is a large epimeron, divided transversely

[1] In many other Homoptera, the episternum and epimeron of the prothorax are well marked.

by a groove which runs out posteriorly to where the descending postnotum fuses with the epimeron. The lower part of the epimeron bears posteriorly a large flap which more or less conceals the 2nd thoracic spiracle, in the membrane between the meso- and meta-thoracic segments.

Note the axillary chord running from the lateral extension of the scutellum to the posterior margin of the wing, and immediately above it lies the posterior (4th) axillary sclerite, better seen in this view than in the dorsal one.

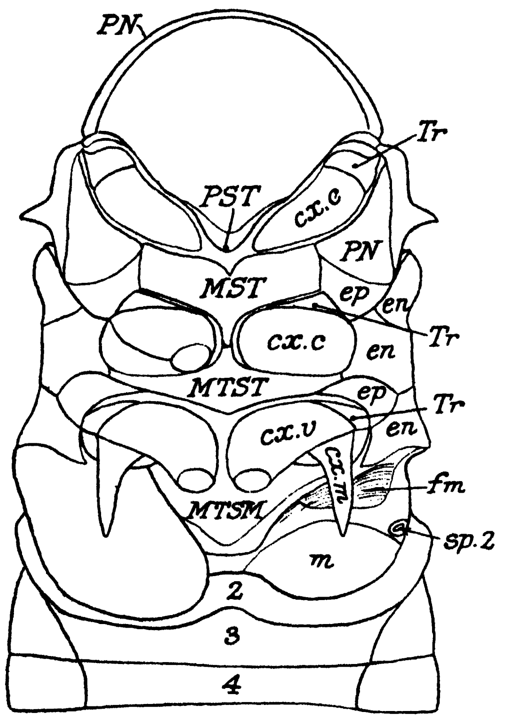

FIG. 77.—Cicada ♂. Ventral view of thorax and ant. abdominal segments. The left operculum removed to expose the mirror (*m*), the folded membrane (*fm*), and the second abdominal spiracle (*sp.* 2) in the cavity in which they lie.

Other lettering as in Fig. 76.

The pleural region of the metathorax shows a straight pleural suture, marking off anteriorly the episternum bounded below by the trochantin and the metasternum. In the male, the epimeron is produced backwards into a large expansion, the operculum, but, in the female, it is only slightly developed. (*N.B.*—The form and size of this operculum in the male differs markedly in different species.)

In the metathorax, note also the axillary chord, as mentioned in the description of the dorsal view, and note the narrow scutellum, fused to the postnotum, the end of which is fused with the epimeron.

Note that the coxæ of the mid- and hind-legs are composed of two parts, a large main piece, the coxa vera, and a smaller posterior piece, the meron; the latter, in the metathorax, lengthening into a strong blade, the meracanthus (see Fig. 76).

Thorax. Ventral view. The thoracic sterna are easily seen in a ventral view, the prosternum, reduced to little more than a small median lobe; the mesosternum, a large transverse plate in front of the 2nd coxæ, and the metasternum, a narrow plate between the 2nd and 3rd coxæ and imperfectly marked off on each side from the episternum. By removing the opercula, however, a large backward extension of the metasternum, the metasternellum, is exposed (see Fig. 77).

Abdomen. The abdomen, in dorsal view, consists of nine *visible* terga in both sexes. There are actually ten segments, but the last is not visible under normal conditions. The sterna differ in the two sexes. Seven are visible in the male (sterna 2 to 8), while only six are visible in the female (sterna 2 to 7),

the ovipositor, sheathed by the large curled sides of the 9th tergum, projecting backwards behind the last. In both sexes the sternum of the 1st abdominal segment is fused to the metathoracic sternum so that the apparent 6th sternum in the male, which underlies both the 7th and 8th terga, is the true 7th, the 8th sternum underlying the 9th tergum, while, in the female, the true 7th underlies the 7th tergum. (*N.B.*—The 7th sternum in the male is frequently large and its form is of use in the classification of the Cicadas.)

There are eight pairs of abdominal spiracles in both sexes, the 3rd, 4th, 5th, 6th and 7th pairs being easily recognized on the lateral borders of the sterna. The 8th spiracles, which are slightly larger than those in front, are in the membrane behind, and concealed by, the tergum of that segment, which curls round the sides, and they are more easily seen in the female.

The 1st abdominal spiracles are larger in the male than in the female and are situated just behind the point where the metathoracic postnotum fuses with the epimeron [1] (see Fig. 76).

The 2nd abdominal spiracles in the female are to be found in the anterior face of the 2nd segment and are concealed under the small backwardly-projecting flap of the metathoracic epimeron. They are easily seen by gently pressing the abdomen upwards so as to separate the ventral regions of thorax and abdomen. They will be found in the corresponding position in the male, but are more easily seen when examining the musical apparatus.

The Musical Apparatus. Cut off the left operculum and also the forwardly-projecting flap on the left side of the 2nd abdominal tergum and thus expose two cavities. The musical apparatus consists of three structures, two of which lie in the ventral cavity and one, the most conspicuous, in the lateral one. This is the drum or timbale and is the actual noise producer. It belongs to the 2nd segment.

Note that the 1st abdominal spiracle is visible just in front of and slightly below the timbale (see Fig. 76).

In the ventral cavity note a white crinkled membrane just outside the anterior margin of a deep pit. This is the "folded membrane" and belongs to the 1st segment. Posteriorly, in the pit, is a tightly-stretched glass-like membrane, the mirror. Close to the lateral margin of the mirror will be seen the 2nd abdominal spiracle (see Figs. 75, 76 and 77).

Now, after removing the head, cut the insect into two by inserting the point of a pair of scissors in the prothorax and cutting along the median ventral line and returning along the median dorsal line. This reveals the presence of a large median abdominal air-cavity extending back to the 4th or 5th segment. In either half of the body note that, about half-way along, there is visible through

[1] There has been some considerable difference of opinion as to whether this pair of spiracles is a 3rd thoracic pair, owing to their position being in what is regarded as part of the metasternum. There is little doubt, however, that these spiracles belong to the 1st abdominal segment.

the transparent wall a large muscle running dorso-ventrally. Remove the transparent wall and note that the broad base of the muscle is attached to a median ventral keel and that the narrower end is connected to the underside of the timbale in such a way that the membrane of this structure can be pulled inwards by the contraction of this large muscle. The rapid "bending" of the drum causes the noise.

Having removed this muscle, note a smaller one lying deeper and running between the anterior margin of the timbale, just beside and posterior to the 1st thoracic spiracle, and a projecting chitinous strut at the dorsal end of the folded membrane. This muscle pulls in the folded membrane and thus varies the size

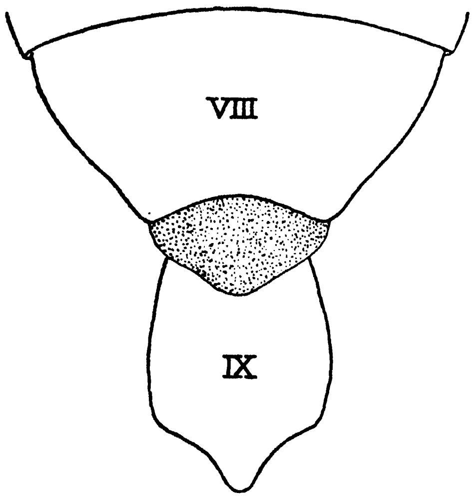

FIG. 78.—Cicada ♂. Dorsal view of apex of abdomen extended after boiling in potash.
VIII = 8th tergum; IX = 9th segment (pygophor).

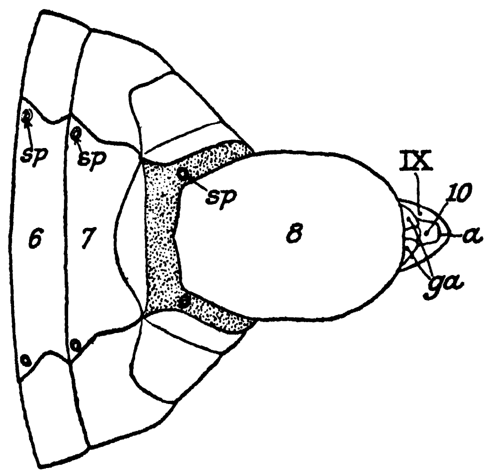

FIG. 79.—Cicada ♂. Ventral view of apex of abdomen. Parts in normal position.
a = anus; *ga* = apex of genital armature projecting from the pygophor (segment 9); *sp* = spiracle; IX = projecting dorsum of segment 9; 6, 7, 8 = sterna.

of the median cavity and this alters the pitch of the noise. The mirror has no muscle attachments and is, presumably, a "sounding board."

The Genital Armature of the Male. Examine the apex of the abdomen in a state of rest, noting the broad 8th tergum and the pointed 9th and, on the ventral side, the large 8th sternum, followed by a small 10th. As in Heteroptera, the 9th segment is capsular in form, a "pygophor," with a cavity in which are the 10th segment and the armature (see Figs. 78 and 79).

Note the pair of large ventro-lateral spines on the 9th segment, the "genital styles," which are probably the reduced gonocoxites, structures well developed in most Homoptera.

In order to see the contents of the cavity of the segment, remove the posterior part of the abdomen, preferably from segment 7, and boil in potash. After boiling, the pygophor will probably be transparent and the ædeagus will be

visible within, bent upon itself near its base, the apex just projecting from the cavity (see Fig. 80).

It will now be possible to extend the armature by gently holding the apex of the ædeagus with fine forceps and pulling it very carefully. This should expose its whole length, including the basal plates (basal piece), and segment 10, which lies above and dorso-laterally to it, will also be exposed (see Figs. 81 and 82).

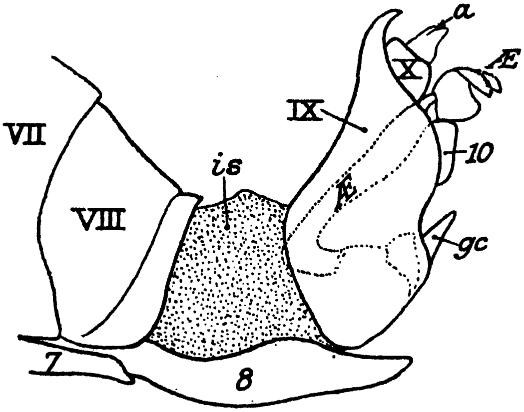

FIG. 80.—Cicada ♂. Side view of apex of abdomen, extended after boiling in potash.

a = anus; *Æ* = ædeagus; *gc* = ventro-lateral spine, probably gonocoxite; *is* = intersegmental membrane; Roman numerals (excepting IX) = terga; IX = 9th segment (pygophor); Arabic numerals = sterna.

Note the absence of parameres which, however, are present in most Homoptera.

The 10th segment possesses on each side a downwardly-directed curved hook and these hooks have been regarded as representing the cerci, as they are in the position where these might be expected to occur. They are not, however, articulated and, apparently, cerci are absent throughout the Order Rhynchota.

The Genital Armature of the Female. The large ovipositor is composed of three pairs of structures, one pair being the

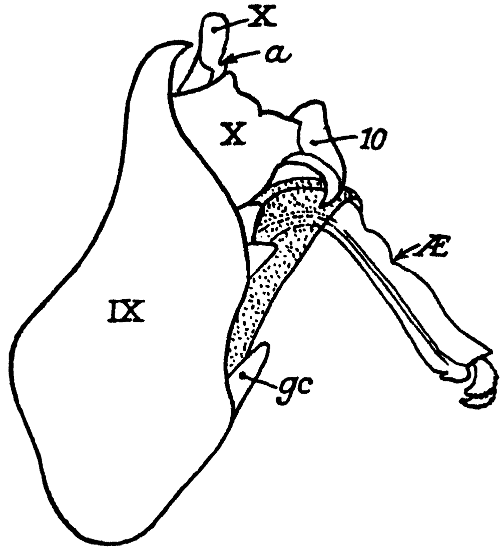

FIG. 81.—Cicada ♂. Side view of pygophor (9th segment) with 10th segment and ædeagus exserted. Lettering as in Fig. 80.

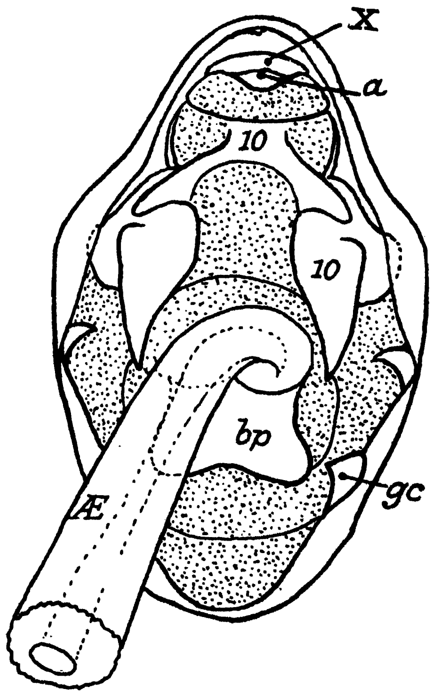

FIG. 82.—Cicada ♂. Looking into the posterior end of segment 9 (pygophor) with the ædeagus exserted. *bp* = basal piece of ædeagus; otherwise lettering as in Fig. 80.

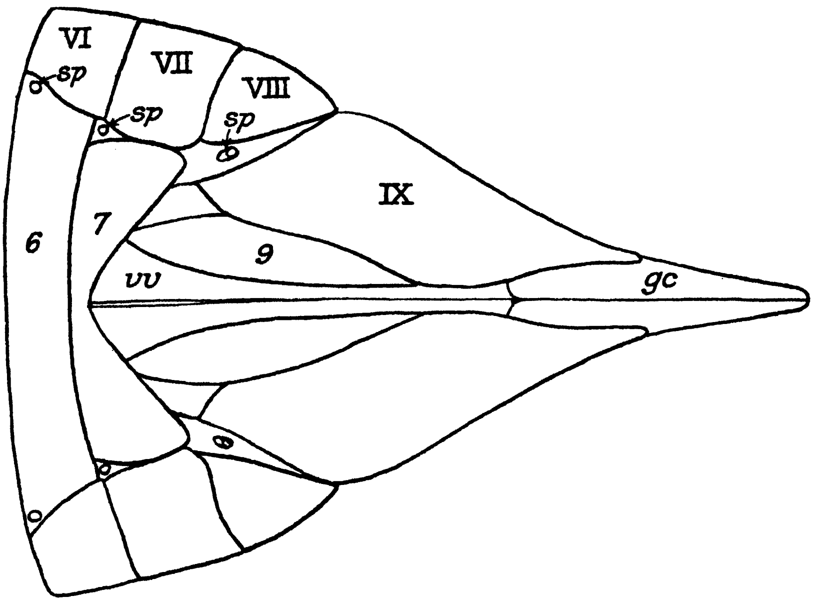

FIG. 83.—Cicada ♀. Ventral view of abdomen, showing the ovipositor in a state of rest. *gc* = the gonocoxites, forming the ovipositor sheath; *sp* = spiracle; *vv* = ventral valves of ovipositor, appendages of segment 8; Roman numerals = terga; Arabic numerals = sterna.

appendages of the 8th segment, while the other two pairs belong to segment 9, and these segments have been profoundly modified in connection with them, as in all insects with large exserted ovipositors.

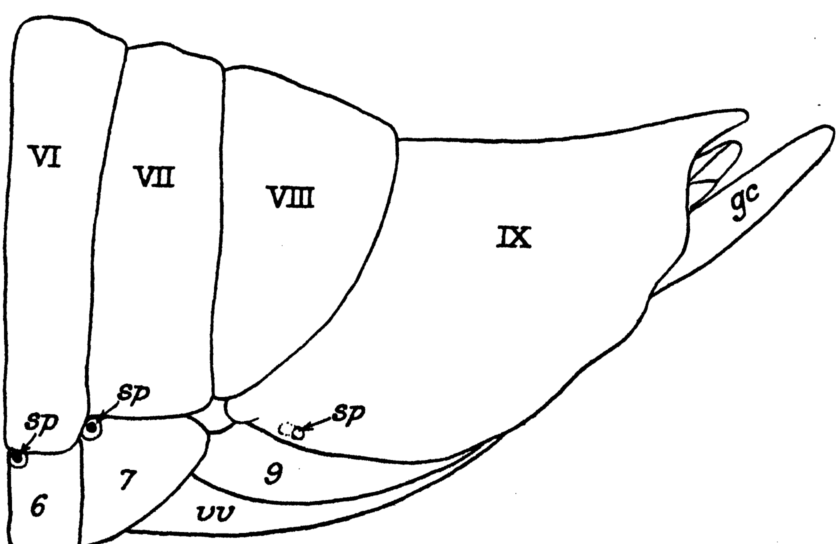

FIG. 84.—Cicada ♀. Side view of apex of abdomen showing the parts in a state of rest. Lettering as in Fig. 83. The last spiracle, that of the 8th segment, dotted in, as it is concealed by the 9th tergum.

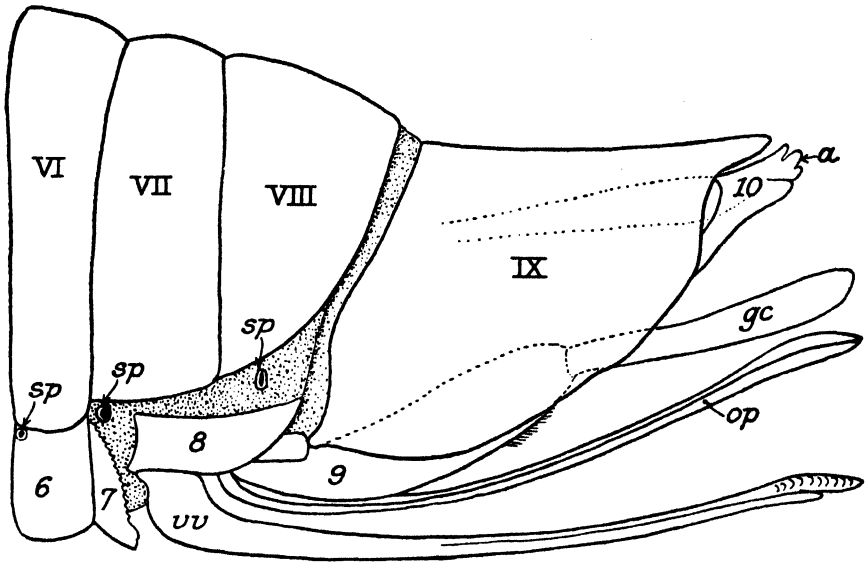

FIG. 85.—Cicada ♀. Side view of apex of abdomen with parts spread out to show the relationships.
a = anus; *op* = ovipositor piercer and guide, like the gonocoxites, appendages of the 9th sternum. The 7th sternum is mostly cut away to expose the 8th sternum, etc. Other lettering as in Fig. 83.

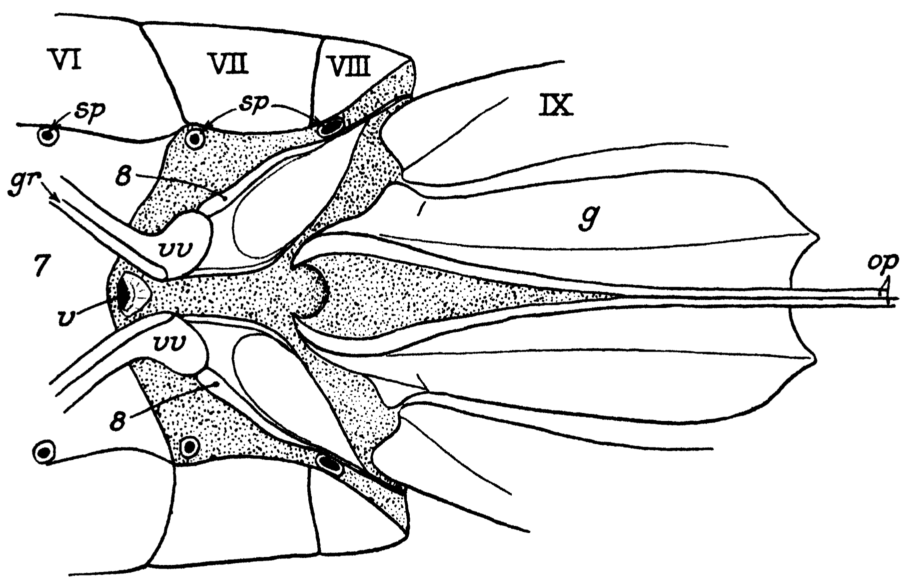

FIG. 86.—Cicada ♀. Ventral view of the base of the ovipositor with the "ventral valves" (*vv*) turned forward, showing the groove (*gr*) in them which fits over a ridge on the piercer (*op*). The main part of the 8th sternum (8) is only seen on edge as it has turned so with the turning forward of its appendages (*vv*).

Other lettering as in Fig. 83.

In the dorsal view, nothing definite can be made out behind the large 9th tergum. In a ventral view, note that the last recognizable sternum, slightly excised posteriorly, is the true 7th and the sides of the 7th tergum are easily identified on each side of it. Behind these, the triangular lobes (one on each side) of the 8th tergum are followed by the very large lobes of the 9th tergum.

The remaining parts will only be definitely identified after boiling in potash, but, before doing this, identify the 8th spiracle in the membrane between the 8th and 9th terga (see Fig. 83).

Note the relationship of the parts in a lateral view (see Fig. 84).

Now boil the posterior part of the abdomen in potash and examine first in side view. Gently separate the parts with a fine needle and note first that apparently five structures compose the ovipositor: (1) a pair of outer sheaths; the gonocoxites, attached to the apex of the 9th sternum; (2) a median (apparently) unpaired structure with a strong piercing point; the so-called "inner valves"; and (3) a pair of processes with serrated apices, attached to the sternum of segment 8, the so-called "ventral valves." (*N.B.*—In order to see this attachment, it will probably be better to cut off the sternum of segment 7.) (See Fig. 85.)

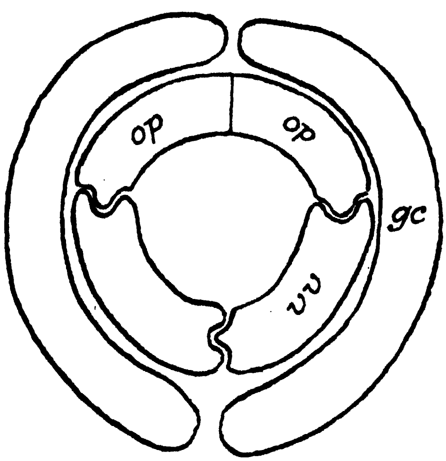

FIG. 87.—Cicada ♀. Diagrammatic transverse section of ovipositor to show relationship of the parts.

gc = the sheath, composed of the gonocoxites of segment 9; *op* = the piercer and guide, fused appendages of segment 9; *vv* = the ventral valves, appendages of segment 8.

Examine the parts in ventral view and note that the vulva opens between the bases of the appendages of segment 8. Part of the 9th sternum is visible on each side of these appendages, but, in order to see the whole of it, bend forward the ventral valves so as to expose the base of the median piercer, attached to the base of segment 9, and it will be seen that this piercer is composed of two appendages fused together except at their bases, which are separated by membrane (see Fig. 86). It is possible to make out certain ridges and grooves on the inner and ventral valves and these, together, form the ovipositor proper, the ridging and grooving allowing the piercer and the other parts to slide forwards and backwards upon one another (see diagram of transverse section, Fig. 87).

Note the serrated surface of one side of the apex of the ventral valves, evidently for lacerating the plant tissues when they are being penetrated for oviposition.

(3) *COLEOPTERA*

EXAMINE the material provided, noting and making drawings of the parts mentioned or, where time does not permit of the completion of all this work, see prepared slides and make drawings from them. In practice, the last three will have to be thus disposed of.

1. A Scarabæid beetle (series Lamellicornia) with lamellate antennæ and 5-segmented tarsi.

2. A Carabid (or Dytiscid) beetle (series Adephaga) with filamentous antennæ and 5-segmented tarsi. The tarsi are simple except where sexual differences occur, when they appear to be more complex than they really are.

Examine and mount the mouth-parts to show the "palpiform" galea of the maxilla or examine mounted specimens and compare with scarabæid mouth-parts.

3. A Chrysomelid beetle (series Phytophaga) with 5-segmented tarsi, which appear to be 4-segmented, owing to the minute 4th segment being concealed by the 3rd.

4. A Tenebrionid beetle or a Melöid (series Heteromera) with 5-segmented tarsi on front and middle legs and 4-segmented tarsi on the hind-legs.

5. A Cerambycid or "Longicorn" beetle (series Phytophaga) with the same type of tarsi as (3) but with quite different antennæ.

6. A Curculionid beetle (series Rhyncophora) with 5-segmented tarsi in which one segment is very small.

Examine the antennæ and note that (usually, though not always in the series) these appendages are "elbowed" with a long 2nd segment to the "Scape."

7. A Hydrophilid (series Polymorpha) in which the antennæ are clavate at the apex and on this character a group within the series is known as the Clavicornia.

Note also the maxillary palpi which are long and "antenna-like." They function beneath the water as antennæ, these latter structures being tucked under the sides of the head and only being brought out when the insect comes to the surface to renew its air supply, when the "club" breaks the surface film, or when the insect is out of the water.

Because of the prominence of the maxillary palpi and the concealment of the antennæ, these aquatic clavicorns have been called "Palpicornia."

The Mouth Parts. Examine the mouth-parts of some of the specimens already used, especially noting those of the Curculionid in which the maxillary palpi and labial palpi are short and rigid instead of flexible.

In those beetles which visit flowers in search of pollen or nectar, the mouth-parts tend to be more fringed with hairs than in others. Compare, e.g. Aulacophora (a Chrysomelid leaf-eater), with a Cicindelid, which is carnivorous, and compare these with Zonitodema, a Melöid. Nemognatha has maxillæ lengthened

out so that, together, they form a proboscis similar to that in Lepidoptera, except that it will not roll up.

The adaptation to the taking of liquid food rather than solid can be seen in several Coleoptera; e.g. in Gyrinid larvæ and in Lampyrid larvæ, the mandibles are pierced, each by a fine tube running from just beneath the apex to the base.

In certain Dytiscid larvæ similar tubes exist, while in others the mandibles are grooved along the inner face, presumably showing a stage in the evolution of the tubes.

In all these the mandibles hold the prey and digestive fluid is pumped out through the tubes, and digested or dissolved fluids are sucked up them.

Wing-Venation. The modifications of the Coleopterous wings have affected the venation so that, in the elytra, no veins are visible except in the pupa, and in the metathoracic wings complex folding has produced great changes. Only three main types of venation are recognizable, although there are very great differences in the venation in different families.

These types do not fit into any recognized system of classification and they have been called:

1. The Adephagid type.
2. The Staphylinid type.
3. The Cantharid or Telephorid type.

The first type (e.g. wing of a Tiger-beetle (Cicindela) or a Carabid or Dytiscid) is the most primitive in that the principal veins are still recognizable and also there are some cross-veins and there is usually a closed cell, the "oblongum," in the middle of the wing, which is characteristic of this type. It is formed by the two cross-veins running between M1 and M2 (or, according to Tillyard's nomenclature, between M and Cu).

In the second type (e.g. wing of Devil's Coach-horse (*Ocypus olens*) or other Staphylinid or of a Burying beetle (Necrophorus sp.)) note the absence of cross-veins and the disappearance of the basal half of Media 1.

In the third type (e.g. wing of a Cerambycid, Melöid or Telephorid) note the fusion of M1 and M2 (or M2 and Cu1, according to Tillyard) towards the margin of the wing and their continuance to the margin as one vein. Associated with this character there are a few cross-veins, especially in the anal region of the wing.

A drawing should be made of a wing of each of the three types and wings of various beetles should be examined and also of some Coleopterous pupæ.

(4) Types of Larvæ of Coleoptera

The beetle larva consists of a head, three thoracic and ten abdominal segments, but, unlike the Lepidoptera, where one larval type is constant throughout the Order, in the Coleoptera the larval form differs greatly in different families.

First, there are two distinct types of larva, the Campodeiform, the more primitive and carnivorous type, and the Eruciform, mostly a vegetarian type.[1]

1. *The Campodeiform type* is best exemplified in the Adephaga and in certain families outside that series, e.g. Staphylinidæ.

The Carabid Larva. The head, in dorsal view, shows sutures dividing two epicranial plates from a triangular fronto-clypeus. There is no labrum. (*N.B.*—The presence or absence of a labrum is often of importance in the determination of beetle larvæ.) Note on each side the six simple eyes (ocelli) concentrated in a ring just behind the base of the antenna, the latter being 4-segmented. (*N.B.*—The number of antennal segments is often of importance in the determination of beetle larvæ.)

Note the large curved mandibles, each with one or more teeth near the base. Each mandible is grooved along its inner face, the groove being lined with soft membrane, an indication that the larvæ suck the blood of their prey. (Cf. Dytiscid larvæ, some of which have similar grooved mandibles, while others have the groove sunk and converted into a tube. Cf. also larvæ of Gyrinidæ and of Lampyridæ which also have mandibles with tubes running through them.)

The maxillæ are elongate and simple, each with a 3-segmented palp and with a 2-segmented galea and a small 1-segmented lacinia. The labium, as in most beetle larvæ, has 2-segmented palps. The thoracic and abdominal segments are very much alike, except that the former bear the legs. Note that the leg consists of six segments, the apical one bearing a pair of claws. (*N.B.*—All beetle larvæ, other than the Adephaga, have only 5-segmented legs and one claw.) The thoracic spiracle is in the mesothorax. The position of this spiracle varies in beetle larvæ. In some it is prothoracic, in others it is between pro- and mesothorax and in some it is in the mesothorax and, as it is often consistent throughout families, its position is of systematic importance. The 10th abdominal segment is tubular, is known as the "anal tube," and projects between a pair of segmented cerci, which are attached to the 9th segment. (*N.B.*—Segmented cerci only occur in a few families of Coleoptera.)

There are eight pairs of simple spiracles on the first eight abdominal segments.

2. *The Eruciform type*, although occurring in the majority of families of Coleoptera, varies greatly and it would require a great number of examples to cover all the variations.

A few examples must suffice:

(A) **The Lamellicorn Larva** (larva of Chafer or Dung-beetle) has a form which has been given the name "Scarabæoid type." The legs are moderately long and the head is large. The body is soft and wrinkled and curved ventrally and has the posterior end rounded and frequently enlarged, so that the larva

[1] In Hypermetamorphic species, the first-stage larva is usually campodeiform and the larva becomes eruciform at the first moult.

usually lies on its side. The head shows distinct clypeus and labrum; there are no ocelli. The antennæ may be 3- or 4-segmented, according to species; the mandibles are large, each with a grinding base known as a "mola." The maxillæ are simple with 4-segmented palps. There is one pair of spiracles in the prothorax and the abdomen has the usual eight pairs.

The Scarabæoid type is not confined to the Lamellicorn series but it occurs in certain other groups, e.g. Ptinidæ, Scolytidæ, etc., but the Lamellicorn can always be recognized because its spiracles are peculiar. They are "sieve-plate spiracles," crescent or horse-shoe-shaped, a type not found in other Scarabæoid larvæ.

(B) **The Curculionid Larva** (the Pine-weevil (*Hylobius abietis*) or the Clay-coloured weevil (*Otiorrhynchus picipes*), etc.).

The head is much as in the Lamellicorn, but the antennæ are minute tubercles, just behind the bases of the mandibles. The latter are without mola; the maxillary palpi are 2-segmented. The spiracles are arranged as in the Lamellicorn but are of a different type, known as "biforous," a type found in a number of families and showing a number of variations (see Fig. 44).

(C) **The Tenebrionid Larva** (the Meal-worm).

Note that the whole larva is enclosed in a hard chitinous exoskeleton. The head has a labrum and shows the same sutures as the previously mentioned larvæ. The mandibles have a mola. There are no ocelli. The thoracic spiracles are in the mesothorax, and the abdomen has the usual eight pairs. The spiracles are simple. On the tergum of the 9th abdominal segment note the pair of small spines. (*N.B.*—The presence or absence of spines is of systematic importance and can be used in a key for determining beetle larvæ.) The 10th segment is small and looks as if it were a ventral appendage of the 9th.

(D) **The Elaterid Larva** (the Wire-worm).

Note the similar chitinization to that seen in the Meal-worm. Here, however, the labrum is absent and the mandibles are without the mola. The spiracles are biforous, not simple. Note that in some wire-worms, e.g. Agriotes, there appears to be a large pair of spiracles on the 9th abdominal segment. These, however, are sensory pits and have nothing to do with respiration.

(E) **The Chrysomelid Larva** (species of Galerucella, etc., on willows, sallows, hazels, etc.).

Whereas ocelli are absent or few in number in most burrowing beetle-larvæ, whether in soil or in wood, in the Chrysomelids, which are mostly leaf-eaters, the usual six ocelli are present just outside the bases of the minute antennæ. The labrum and clypeus are present and the mandibles are without a mola. The prothoracic tergum is chitinized throughout, but the rest of the body is soft and warty in appearance. The anal tube is well developed and sometimes has the ventral (anterior) margin projecting into proleg-like processes. The thoracic

spiracles are between the pro- and meso-thorax and all spiracles are raised upon small "warts."

Systematic Characters

In determining the family to which a beetle-larva belongs certain characters are of prime importance, namely:

(*a*) **Head Characters.**

1. Number and positions of ocelli. (These are usually very difficult to see in the mounted skins, though easily seen in the larva itself.)

2. Number of segments in the antennæ. (There is usually a basal ring which is apparently part of the head and within which, if the antenna is at all retractile, the organ can be withdrawn.)

3. The mandibles. The presence or absence of a mola.

4. The number of segments in the maxillary palpi.

5. The presence or absence of a labrum.

(*b*) **Thorax Characters.** The legs are in most beetle larvæ 5-segmented, the apical segment being lengthened out into a single claw which is part of the segment. In the Adephaga, the legs are 6-segmented and there are two movable claws at the apex (with a few exceptions).

(*c*) **Abdomen Characters.** The presence or absence of cerci, segmented appendages, on the 9th abdominal segment and, in their absence, the presence or absence of a pair of projections or processes.

(*d*) **The Spiracles.** The position of the thoracic spiracles (there is only one pair of thoracic spiracles, except in a very few cases). It may be in the prothorax, between pro- and meso-thorax (the most usual position), or in the mesothorax. The nature of the spiracle, simple, biforous or sieve-pattern.

To prepare a Beetle-larva as a Microscope Slide

Take a larva, e.g. a Meal-worm. It is immaterial whether it has been freshly killed or has been in spirit for an indefinite period. Turn it ventral side uppermost and introduce the point of a fine dissecting-needle, or preferably a very fine scalpel, beneath the posterior margin of the prosternum and again behind the penultimate abdominal segment, in each case making a short transverse slit. This is to allow easy penetration of the solvent.

Place the larva in a test-tube with strong potash. If time is of no importance, allow the potash to act cold, leaving the larva until the contents have dissolved and appear like thick soup; otherwise boil the potash until this result is obtained or the contents have been forced out.

Now insert a finely drawn point of a glass tube into the posterior slit and apply the mouth to the other end, preferably attaching a piece of rubber tubing to allow flexibility between the mouth and the insect. By alternately blowing and sucking very gently, all the soup-like contents of the larva can be driven out at the anterior slit and possibly also the insoluble tracheal trunks may also project

from there. If so, remove them carefully with fine forceps. When the skin is quite clean remove from the potash into water and wash, inside and out, to make sure of removing all the potash. Then place in 70 per cent. spirit and proceed in the usual way to oil of cloves. In the case of small larvæ, replace the oil of cloves with xylol and then with balsam and mount under a cover-slip in the usual way but, with larger larvæ, it will be necessary either to place pieces of glass on the slide before putting on the cover-slip or, preferably, the skin can be compressed for some days between two slides bound together with cotton and submerged in xylol until the "springiness" is taken out of it and it will lie flat for ordinary mounting.

Although practice is necessary to ensure the proper mounting of beetle-larvæ, time will not permit of much if a proper study of larval characters is to be achieved. The student should, therefore, be supplied with prepared slides of some or all of the following families: Byrrhidæ, Byturidæ, Carabidæ, Cicindelidæ, Cerambycidæ, Cleridæ, Curculionidæ, Dermestidæ, Elateridæ, Endomychidæ, Gyrinidæ, Lampyridæ, Melöidæ (Triungulin stage), Pyrochröidæ, Silphidæ, Staphylinidæ, Telephoridæ.

(5) Key for Determining the Families of the Larvæ of Coleoptera

Based upon A. D. Macgillivray's key, 1903

1. Legs composed of six segments; tarsi usually with two claws 2
1. Legs composed of five or fewer segments and tarsi with only one claw, or legs absent . 8

2. Mandibles for biting and chewing: with or without teeth at the base or in the middle 3
2. Mandibles suctorial, i.e. with tubes through them or grooves along the inner face . 7

3. Abdomen without long lateral filaments 4
3. Abdomen with long lateral tracheal filaments . . . . Gyrinidæ

4. Ocelli usually six, rarely four, sometimes two or absent. No hooks on the 5th abdominal tergum. Cerci present, sometimes small, rarely absent (e.g. Cybister (Dytiscidæ)). Maxillary palps 4-segmented 5
4. Ocelli four. Hooks on the 5th abdominal tergum. No cerci. Maxillary palps 3-segmented . . . . Cicindelidæ

5. Abdomen and legs ambulatory. Eight pairs of abdominal spiracles . . . Carabidæ
5. Abdomen and legs natatory. Seven pairs (rarely 8, e.g. Amphizoa) of abdominal spiracles 6

6. Tracheal gill filaments at the bases of the legs and below the anterior abdominal segments Pelobiidæ
6. Tracheal gill filaments of Pelobiids absent . . . . Amphizoidæ

7. Apex of the abdomen armed with four hooks. Last segment with four long processes Gyrinidæ
7. No hooks at apex of abdomen. Last segment with two long processes . . Dytiscidæ

8. Cerci present, i.e. appendages composed of one or more segments 9
8. Cerci absent, but unjointed processes may or may not be present 15

9. Ocelli in groups of five or six. Larvæ terrestrial or aquatic 10
9. Ocelli in groups of four or two, or absent. Larvæ terrestrial 12

10. Larvæ terrestrial, fungivorous . . . . Scaphidiidæ
10. Larvæ aquatic 11

11. Mandibles suctorial (with tubes running through their length) . . . Haliplidæ
11. Mandibles without tubes . . . . Hydrophilidæ

12. Labrum present, distinct; body more or less "lepismoid," i.e. tapering from the shoulders to the posterior end . . . . Silphidæ
12. Labrum absent; body with the sides subparallel 13

13. Ocelli usually in groups of four. Antennæ 3-segmented [1] . . . Staphylinidæ
13. Ocelli absent. Antennæ 3- or 1-segmented 14

14. Ninth abdominal segment but little, if any, longer than the preceding ones. Spiracles biforous. Larvæ not minute . . . . Histeridæ
14. Ninth abdominal segment much longer than the preceding ones. Spiracles simple. Larvæ minute . . . . Trichopterygidæ

15. Larvæ without legs (except first-stage larvæ of Bruchidæ) 16
15. Larvæ with legs 19

16. Body depressed. Head broad and flat. Larvæ wood-borers 17
16. Body cylindrical. Head not broad and flat 18

17. Maxillary palpi 3- or 4-segmented; labial palpi 3-segmented. Ocelli may be present Cerambycidæ
17. Maxillary palpi 2-segmented; labial palpi unsegmented, minute. Eyes usually absent Buprestidæ

18. Spiracles simple, oval with a narrow median slit. Thoracic spiracle between pro- and meso-thorax. Head elongate and partly sunk in the prothorax . . Bruchidæ
18. Spiracles of sieve-plate pattern.[2] Thoracic spiracle as in Bruchids. Head retractile Buprestidæ (Leaf-miners)
18. Spiracles biforous. Thoracic spiracle in prothorax. Head not retractile Rhyncophora (Curculionidæ, Scolytidæ)

19. Larvæ scarabæoid 20
19. Larvæ not scarabæoid 25

20. Ocelli present; two or more on each side 21
20. Ocelli absent or only one ocellus on each side 23

21. Pronotum with a spinous process . . . . Bruchidæ
21. Pronotum without spinous process 22

22. Six ocelli; case-bearing larvæ, usually bulging and curled back upon themselves at the posterior extremity. Body segments not showing transverse folds Chrysomelidæ (Clythrinæ and Cryptocephalinæ)

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[1] Be careful not to mistake the basal ring of the antenna for a segment (see p. 139).
[2] The sieve-plate of Buprestids is of a different form from that in Lamellicorns.

22. Two ocelli; larvæ are not case-bearers. Body segments showing transverse folds Scarabæidæ (Troginæ)

23. Antennæ 3-segmented, always minute, scarcely projecting Lyctidæ, Ptinidæ and Anobiidæ
23. Antennæ 2- to 6-segmented, not minute, generally as long as, or longer than, the mandibles 24

24. Body gradually tapering posteriorly; 9th abdominal segment small . . Bostrychidæ
24. Body not tapering; last segment larger than the preceding 25

25. Segments showing transverse folds; antennæ of three, four or five segments Scarabæidæ
25. Segments simple; antennæ of three or four segments . . . . Lucanidæ

26. Apex of the abdomen (9th segment) without two or more processes or spines, unless similar processes, possibly smaller, occur on other abdominal segments. Last visible segment (9th) not strongly chitinized unless the whole body is similarly chitinized 27
26. Apex of the abdomen with two or more processes or spines, the rest of the body being without them. Last visible segment usually, but not always, strongly chitinized as compared with the other segments 52

27. Body densely covered with long fine setæ, generally barbed and frequently aggregated into "pencils" . . . . Dermestidæ
27. Body not densely covered; if setæ are present, they are minute and there are no "pencils." Strong black or brown spines may be present 28

28. Larvæ aquatic 29
28. Larvæ terrestrial 33

29. Antennæ as long as, or longer than, the thorax and of many segments Helodidæ (Cyphonidæ)
29. Antennæ short and not of many segments 30

30. Body flattened dorso-ventrally and with lateral margins of the segments greatly expanded and *with abdominal tracheal gills* . . . . Parnidæ
30. Body cylindrical or somewhat flattened dorso-ventrally; with or without processes but *without tracheal gills* 31

31. Labrum absent; body segments each with four long backwardly-projecting processes. Last abdominal segment greatly lengthened and tapering . . . . Haliplidæ
31. Labrum present; body segments without processes. Last abdominal segment not lengthened 32

32. Eighth abdominal segment with a pair of dorsal spines with a spiracle at the base of each. Larvæ pale yellow: soft-bodied. (On roots of aquatic plants) Chrysomelidæ (Donaciinæ)
32. Eighth abdominal segment without dorsal spines. Larvæ strongly chitinized throughout, suggesting "wire-worms". . . . . Parnidæ

33. Lateral margins of the abdominal terga dilated so as to conceal the pleura, when viewed from above; the dilatations, when elongate, narrowed towards the apex . 34
33. Lateral margins of abdominal terga not dilated 35

34. Body convex: about twice as long as broad. Lateral dilatations blunt and covered with minute setæ . . . . Endomychidæ

34. Body flattened above and distinctly more than twice as long as broad. Lateral dilatations often pointed and never covered with setæ . Lampyridæ and Lycidæ

35. Body covered with strong black or brown spines, not tubercles 36
35. Body without black or brown spines but may have translucent setæ 38

36. Median pair of spines on the 8th abdominal tergum, long and modified for carrying cast skins and fæces . . . . Chrysomelidæ (Cassinæ)
36. Median pair of spines on the 8th segment like those in front. If any spines are elongate, they are on the 9th segment 37

37. Median pair of spines on the 9th segment distinctly longer than those on other segments . . . . Erotylidæ
37. Median projections or spines on the 9th segment similar to those on other segments Coccinellidæ

38. Body covered with fine clavate setæ 39
38. Body not so covered 40

39. A pair of short, stout spines on the 9th abdominal tergum . . . . . Erotylidæ
39. No stout spines on the 9th segment . . . . Endomychidæ

40. Body covered with a fine flocculent mass; larvæ aphidivorous . . . Coccinellidæ
40. Body without flocculent mass 41

41. Larvæ with a pair of colourless projections, which may consist of four or five smaller processes, on the underside of the body, just in front of the anus and somewhat resembling prolegs. (They are outgrowths of the ventral margin of the anal tube) Chrysomelidæ (Galerucinæ, Chrysomelinæ, etc.)
41. Larvæ without these false prolegs although the anal tube may be present . . 42

42. Abdominal segments of similar width or tapering posteriorly. Larvæ in burrows in mud or sand in wet places . . . . Heteroceridæ
42. Abdomen widening from the base and contracting towards the apex. A median process at the end of the abdomen. Larvæ in decaying wood . . . . Cupedidæ
42. Thorax bulging laterally, one or all three segments being distinctly wider than the abdominal ones 43
42. Thorax not broader than the abdomen or, if so, the body is widest at the prothorax and gradually tapers to the posterior end 44

43. Abdomen more or less parallel-sided or tapering slightly towards the posterior end. Larvæ in burrows in mud or sand in wet places . . . . . Heteroceridæ
43. Abdomen wider at each end than in the middle. A median process at apex of abdomen. Larvæ in decaying wood . . . . . Cupedidæ (Cupesidæ)

44. Abdomen cylindrical, strongly chitinized throughout and with the apex squarely truncate . . . . Rhipiceridæ
44. Abdomen cylindrical or flattened; usually not chitinized throughout but, if so, the chitin is not dense. Last segment not squarely truncate 45

45. Thoracic and abdominal terga or sterna or both with distinct chitinized areas, frequently prominent. (Something like prolegs) 46
45. Terga and sterna without proleg-like chitinized areas 47

46. Body usually depressed, distance between prothoracic legs greater than the length of the legs . . . . Cerambycidæ

46. Body usually cylindrical. Distance between prothoracic legs not as great as the length of the legs . . . . Œdemeridæ

47. Labrum absent 48
47. Labrum present 50

48. Spiracles simple . . . . Telephoridæ
48. Spiracles biforous 49

49. Body chitinized throughout; cylindrical or sub-cylindrical . . . . Elateridæ
49. Body soft, flattened and rather broad . . . . Lampyridæ

50. Mandibles without a mola. Pronotum distinctly larger than the mesonotum. Spiracles biforous 51
50. Mandibles with a mola. Pronotum not larger than the mesonotum. Spiracles not biforous. Maxillary palpi 3-segmented
Corylophidæ, Sphindidæ, Tenebrionidæ (part), Melandryidæ, etc.

51. Terga of all segments horny and smooth. Those of abdominal segments 8 and 9 much larger than the others. Spiracles in the thorax between the pro- and meso-segments . . . . Byrrhidæ
51. Terga of all segments, except perhaps the prothorax and the last (9th) abdominal, either fleshy, warty or tuberculate. Tergum of the 9th abdominal segment either not much larger than that of the preceding segment or expanded into spathulate form. Tergum of the 8th segment similar to those in front. Mesothoracic spiracle . . . . Chrysomelidæ, Mordellidæ

52. Labrum absent . . . . Elateridæ
52. Labrum present 53

53. Mandibles without a mola 54
53. Mandibles with a mola 61

54. Body densely covered with very long, fine setæ, generally barbed and often aggregated into a "pencil" at the posterior end . . . . Dermestidæ
54. Body without long setæ but may be somewhat hairy 55

55. Apex of the abdomen obliquely truncate . . . . . . Ciöidæ (Cissidæ)
55. Apex of abdomen not obliquely truncate 56

56. Last abdominal segment (9th) somewhat lengthened, strongly chitinized and ending in a short emarginate point (i.e. the two processes are adjacent)
Mordellidæ (Toxomia, Mordella, etc.)
56. Last abdominal segment may be twice the length of the preceding one but has the two processes well separated 57

57. Thoracic terga (one or more of them) more markedly horny than the abdominal terga 58
57. Terga of all segments of much the same consistency 59

58. Notum of the prothorax more horny than the other terga. Meso- and meta-nota with, at most, a pair of horny "islands" . . . . Cleridæ
58. Nota of pro- and meso-thorax more horny than others and similar to one another
Trogositidæ (Ostomidæ)

59. Antennæ of four segments and a basal tubercle 60
59. Antennæ of three segments or less . . . . . . Cucujidæ (Scalidiinæ)

60. Thoracic spiracles prothoracic . . . . Dascillidæ
60. Thoracic spiracles not on prothorax
Mordellidæ (Anaspis, etc.), Mycetophagidæ, Colydiidæ

61. Antennæ of four segments and a basal tubercle. (*N.B.*—They appear to be 2-segmented as 3 is a mere collar and 4 is very minute) . . . Tenebrionidæ (part)
61. Antennæ of less than four segments and a basal tubercle 62

62. Body strongly depressed; last abdominal segment more or less square and about as long as the two preceding segments together . . . . . . Pyrochröidæ
62. Body cylindrical or sub-cylindrical. Last abdominal segment not markedly larger than the others 63

63. Maxillary palpi of four segments
Nitidulidæ (Epuræa, Meligethes), Cryptophagidæ (Antherophagus)
63. Maxillary palpi of three segments 64

64. Thoracic segments with small horny "islands" on the terga; otherwise the body is fleshy . . . . Malachiidæ (Melyridæ)
64. Terga of similar consistency throughout 65

65. Thorax, or part of it, wider than the abdomen; 9th abdominal segment greatly lengthened . . . . Lymexylonidæ
65. Thorax of the same width as the abdomen; 9th segment not greatly lengthened . 66

66. Ocelli six 67
66. Ocelli five, two or absent. 68

67. Spiracles biforous. Ocelli in two vertical rows . . . . Byturidæ
67. Spiracles simple. Ocelli in two vertical rows or otherwise
Cucujidæ (Cucujinæ, Læmophlæinæ)

68. Antennæ of three segments and a basal tubercle . . . . . . Melandryidæ
68. Antennæ of two segments and a basal tubercle . . . . Lagriidæ

(6) *LEPIDOPTERA*

The External Morphology of the Lepidoptera

A Noctuid Moth, e.g. *Triphæna pronuba*, the "Yellow Underwing"

The moth is very hairy and it is necessary to remove the hairs to some extent in order to see the parts. This may be done on a dry specimen by very careful work with a fine pair of forceps but, if another specimen is available for the study of the wings, the whole moth can be boiled in strong potash for about five or ten minutes. This will remove some of the hairs and the remainder will rub off with a brush or can be pulled out with fine forceps.

Head. Note the large fronto-clypeus, the form of the antennæ and the

maxillary proboscis, enclosed on each side by the large labial palpi. Note the large compound eyes and the two ocelli on the vertex.

If time permits, remove the head and, if it has not already been done, boil it in potash and then attempt to remove the maxillæ complete, i.e. with the cardo, stipes, palp and galea. Also remove the labium and make a permanent mount of both structures.

Thorax. After removing the dense hair from the terga of the thorax, note the narrow prothorax. Projecting backwards from the pronotum, on each side of the median line, is a chitinous flap which lies on the mesonotum. These flaps are the "patagia," outgrowths from the pronotum, and are not to be confused with the "tegulæ" which belong to the mesothorax. The mesothorax is large and from the base of each mesothoracic wing there projects backwards a large tegula, the pair of patagia overlying the bases of the two tegulæ. Most of the tegula lies upon the base of the wing, but a special "tegular arm" projects from its base beneath the base of the wing and rests upon the dorsal edge of the pleuron.

The prescutum, although visible at the sides of the large scutum, is very narrow in the middle. The scutellum is distinct behind the scutum and extends laterally into the posterior wing process and the axillary chord on each side. The metathorax is narrow compared with the mesothorax, but its scutum and scutellum are easily recognizable, the latter with the axillary chords running out to the posterior margin of the jugal lobe of the posterior wing (see Fig. 88).

Examine the wings to see the wing-coupling apparatus. The "frenulum," one or more spines (one in the male, the apparent one being really several fused together, and two or more in the female), projecting from the anterior margin of the hind-wing at its base and the "retinaculum," on the underside of the fore-wing. In the male this is a chitinous flap attached to the subcostal vein, but in the female it is a tuft of hairs attached to the cubitus vein. Note the attachment of the wings, the axillary membrane, the axillary chord and the axillary sclerites. These latter are somewhat difficult to determine as there appear to be so many chitinous plates occupying the area.

Snodgrass ("Morphology and Mechanism of the Insect Thorax," *Smithsonian Miscellaneous Collections*, Volume 80, Number 1, 1927, p. 62) laid down certain rules with regard to these sclerites in insects, and it is useful to know them. There are usually only three axillary sclerites, although four occur in some forms, e.g. the Rhynchota. The 1st sclerite is supported by the anterior-wing-process of the notum and its anterior extremity is usually associated with the base of the subcostal vein. Its outer margin articulates along an oblique margin with the 2nd sclerite. This latter is continuous with the end of the radial vein. Below the wing it rests upon the wing-process of the pleuron, when the wing is extended. The 3rd sclerite articulates with the posterior-

wing-process of the notum and the bases of the anal veins are associated with its outer side. The 4th sclerite, when it occurs, lies between the outer extremity of the 3rd and the wing-process with which the third would otherwise be in contact.

Now carefully remove a pair of wings, without damaging them or the thorax, and prepare them for mounting for the study of the venation (see p. 114).

The Wing (see pp. 114–116).

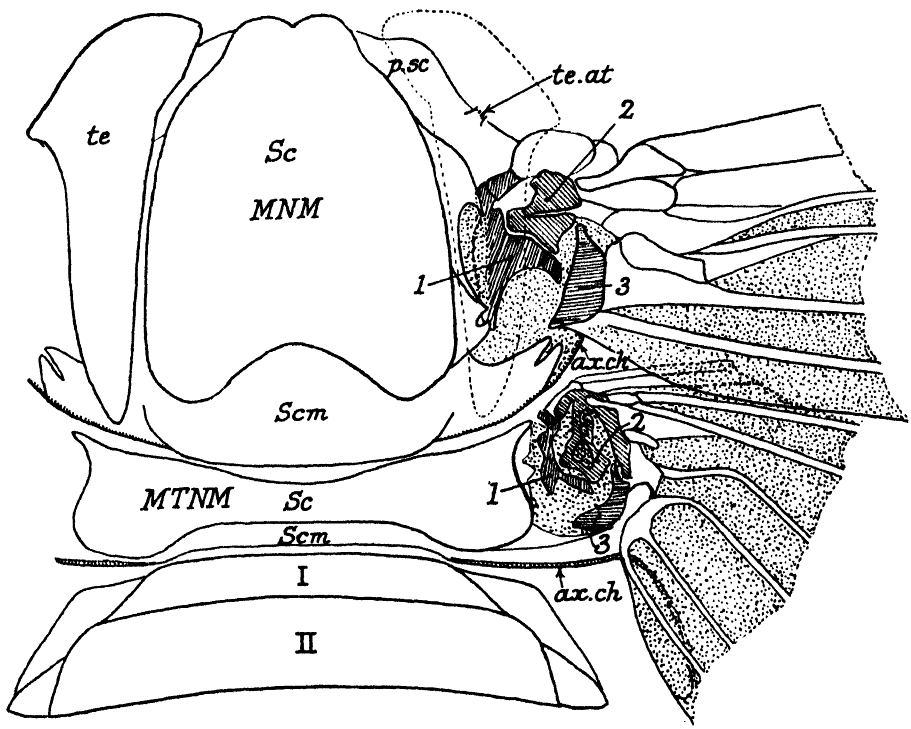


FIG. 88.—A Sphingid Moth. Dorsal view of meso- and meta-thorax and anterior abdominal segments. *ax.ch* = axillary chord; *MNM* and *MTNM* = meso- and meta-notum; *p.sc* = prescutum; *Sc* = scutum; *Scm* = scutellum; *te* = tegula; *te.at* = attachment point of tegula; 1, 2, 3 = axillary sclerites; I, II = 1st and 2nd abdominal terga.

The Pleura of the Thoracic Segments. Lay the moth on its side, preferably under water if it has been boiled in potash, and put a pin through the eyes to fix it to the support. Pin the wings above the body so as to expose the whole of the side of the thorax and abdomen.

First recognize the limits of the meso- and meta-pleura by finding the pleural sutures in the usual way and then identifying the episterna and epimera. (*N.B.*—The pleural suture of the mesopleuron does not run straight, like that of the metapleuron, but zigzags slightly.)

Note the large coxæ of the meso- and meta-thoracic legs, fused to the

thorax and divided into coxa vera and coxa meron by a vertical suture. The prothoracic coxa has no meron.

The Thoracic Spiracles. As in most insects, there are two thoracic spiracles. The 1st lies between the pro- and meso-thorax, in the membrane, in a line between the middle of the compound eye and the top edge of the meso-episternum. The 2nd lies between the meso- and meta-thorax, just in front of the top edge of the meta-episternum. Some authors, including Tillyard, have stated that there is only one thoracic spiracle, but others, including West-

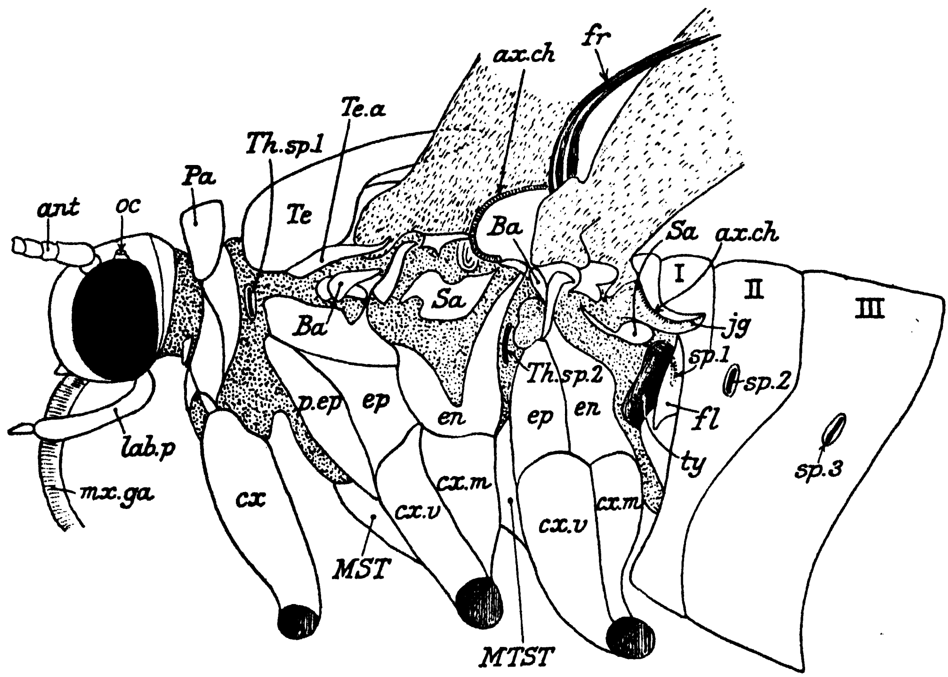


FIG. 89.—Noctuid Moth. Side view of head, thorax and part of abdomen.

ant = antenna; *ax.ch* = axillary chord; *Ba* = basalare (ant. epipleurite); *cx* = coxa; *cx.m* = coxa meron; *cx.v* = coxa vera; *en* = epimeron; *ep* = episternum; *fl* = flap covering 1st abdominal spiracle (*sp.*1); *fr* = frenulum; *jg* = jugum of wing; *lab.p* = labial palp; *MST*, *MTST* = meso- and meta-sternum; *mx.ga* = galea of maxilla; *oc* = ocellus; *Pa* = patagium; *p.ep* = pre-episternum; *Sa* = subalare (post. epipleurite); *sp* = spiracle; *Te* = tegula; *Te.a* = tegula arm; *Th.sp.* = thoracic spiracle; *ty* = entrance to tympanal cavity.

wood, Scudder, Minot, Sharp and Imms, have described two. The reality of the 2nd is easily proved by splitting the specimen longitudinally and examining the spiracle from the inside, when the trachea running from it will be found (see Fig. 89).

The Abdomen in the Male.

As has already been pointed out, the sexes can be separated by an examination of the wing-coupling apparatus.

Examine the abdominal terga of the male, first clearing away most of the

hair as already described. Note that, in all, eight complete terga are recognizable. There are actually ten segments, but the last two are greatly modified and reduced in connection with the genital armature and, in a state of rest, they lie concealed, more or less completely within the 8th. Examine the sterna and note that only seven are recognizable, owing to the first being absent or membranous, as in most insects.

The 1st segment has a small tergum, fused along its anterior border to the metathorax and, on each side of this, just beneath the jugum of the hind-wing, is a small tunnel leading into a comparatively large "tympanal cavity," supposed to be auditory (see Fig. 89).

Projecting forward from the abdomen and across the tunnel entrance is a small lobe and beneath this is the 1st abdominal spiracle, i.e. lying at the entrance to the tympanal cavity. This tympanal cavity appears to owe its existence partly to the metathorax and partly to the 1st abdominal segment. According to Eggar ("Das thoracale bitympanale Organ einer Gruppe der Lepidoptera Heterocera," *Zoologische Jahrbuche Anat.*, XLI, 1919), the tympanum receives its nerve from the last thoracic ganglion. On the other hand, the 1st abdominal spiracle is associated with the structure.

Note that the tympanal cavities vary in different forms and are absent from many Lepidoptera, but they happen to be large in this species. (*N.B.*—In specimens which have been boiled in potash, the tympanal cavities can be explored as the 1st abdominal tergum will usually tear away smoothly and evenly from the postnotum of the metathorax.)

The Abdominal Spiracles. Once the 1st spiracle has been found, it is not difficult to recognize the other six, which lie more or less in a line with it, in the middle of each of the segments 2 to 7. There are no spiracles on the 8th segment in the imago, but spiracular scars are visible on this segment in the pupa and functional spiracles occur here in the larva.

The Genital Armature. In order to see the male genital armature, remove the abdomen and boil in potash until everything, except the chitin, has disappeared. Two converging pointed processes will now be seen projecting from the posterior end of the abdomen. If the body is held with a pair of forceps and, with another pair, one of these processes is pulled gently, it will be easy to extend the body to its full length and thus to expose the whole armature.

Now examine the parts *in situ*. The pointed processes, already referred to, are the apices of two large lateral lobes, the "valves." These valves are the coxites of the 9th segment and are therefore the homologues of the "basal piece" of Coleoptera, the "subgenital plates" of Rhynchota Homoptera and the "claspers" of the Heteroptera.

Trace these valves to their attachment to the sides of the 9th segment, the "tegumen." Note that at their point of attachment there is a joint, above

which is the tergum and below which is the sternum which, in the median ventral line, enlarges into a globular structure, the "saccus."

Attached to the median line of the tergum is a curved, backwardly-projecting process, the "uncus," below which is the anal tube with the anus at its apex. The uncus either represents all that is present of the 10th segment or, as is suggested by Zander, is an appendage of that segment, the segment itself having been reduced to membrane within the 9th.

In many forms there projects downwards, on each side from the base of the uncus, a chitinous ring, either complete or broken. In its complete condition it surrounds the anal tube. This is the "scaphium" or "gnathos" and it is either the sternum of the 10th segment or an appendage of the absent sternum.

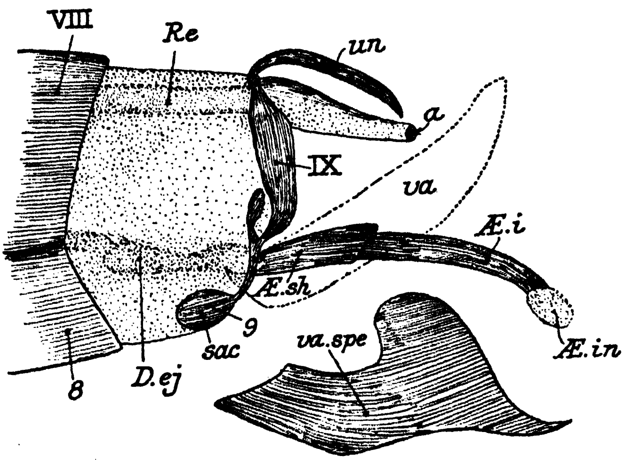


FIG. 90.—Noctuid Moth ♂. Lateral view of genital armature, extended after boiling in potash.

a = anus; *Æ* = ædeagus; *Æ.i* = intromissive part; *Æ.in* = internal sac; *Æ.sh* = sheath; *D.ej* = ductus ejaculatorius, seen through intersegmental membrane; *Re* = rectum, seen through intersegmental membrane; *sac* = saccus, median lobe of 9th sternum; *un* = uncus; *va* = valve (gonocoxite) dotted in; *va.spe* = valve of *Triphæna pronuba*, for comparison; VIII = 8th tergum; IX = 9th tergum; 8 and 9 = sterna.

Passing through the middle of the 9th segment and lying beneath the anal tube and between the bases of the valves, is a chitinous structure, the base of the ædeagus, which contains an eversible portion, the intromissive organ, in which runs the ductus ejaculatorius. From the apex of the tube can be drawn out the "internal sac," an eversible membranous apical portion of the ædeagus. Note that the ædeagus possesses no recognizable "basal piece," unless the sheath is the homologue, which seems unlikely. A structure known as the "juxta" or ring-wall has been described for some forms, but it is absent in this type and is not homologized with the basal piece.

Note also the absence of any structures representing the parameres (see Fig. 90).

Now examine one of the valves and note that, along its dorsal edge, there is a slight thickening which ends posteriorly in a small inwardly-projecting point. This is the "costa," a part often much more elaborated and more clearly marked off from the middle part, the "valvula." On the inner side of each valve there projects upwards from the ventral edge of the valvula a large part, the "sacculus." This, again, is often greatly developed and the two sacculi may even unite together into a median "furca." The inner side

of the valve frequently possesses tufts of spiny processes, the "harpes," [1] absent in this type.

All these points are of great importance in systematic work.

The Abdomen in the Female

Nothing calls for comment in the first six segments, which are much as in the male. The 7th is also very like that in the male except that the sternum is excised in the median line. The 8th segment is partly membranous and, in a state of rest, this segment and the rest of the abdomen behind it is completely withdrawn within the 7th so that, in what appears to be the posterior wall of the 7th, a small chitinous ring surrounding an oval hole will be visible (see Fig. 91). Boil abdomen in potash and then very carefully hold this ring with a pair of fine forceps and pull gently. It will thus be possible to expose the apex of the abdomen, segments 8, 9 and 10. The boundary between the 8th and 9th segments will be easily recognized, but the two segments 9 and 10 are so reduced that they cannot be identified separately. They form the chitinous ring already mentioned and, on each side, is a long chitinous strut projecting towards the 8th segment.

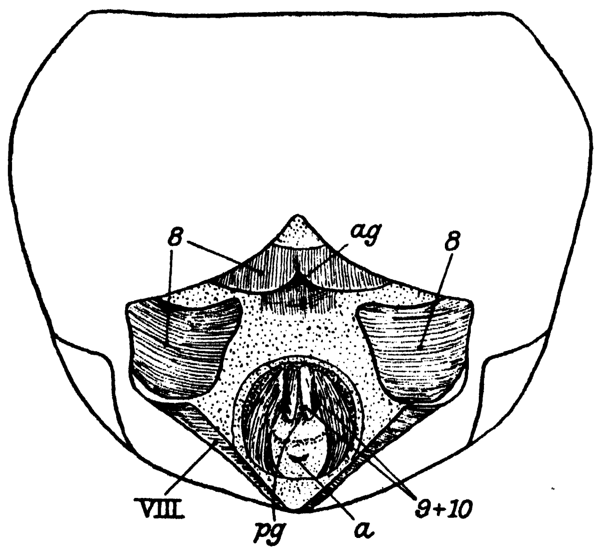


FIG. 91.—Noctuid Moth ♀. Ventral view of 7th abdominal segment, after boiling in potash, showing the 8th, 9th and 10th segments contained within it.

a = anus; *ag* and *pg* = ant. and post. gonopores; VIII = 8th tergum; 8 = 8th sternum; 9 and 10 = fused segments 9 + 10, telescoped into segment 8.

Examine the chitinous ring and recognize, within it, two separate openings, a dorsal and a ventral. The dorsal is the anus and the other is the posterior or ovipositing gonopore.

Examine the sternum of the 8th segment, noting the irregular chitinization and, medianly, a separate chitinous plate. Between the ring and the plate is the anterior or copulatory gonopore. Explore this, opening up the sternum of the 7th segment so as to see the strong chitinous end of the vagina which connects directly with this anterior gonopore (see Figs. 92, 93 and 94).

[1] The term "harpes" was used by Pierce (*Genitalia of the Noctuidæ*, etc., 1909, 1914, 1922) for the valves, which have also been called the "claspers."

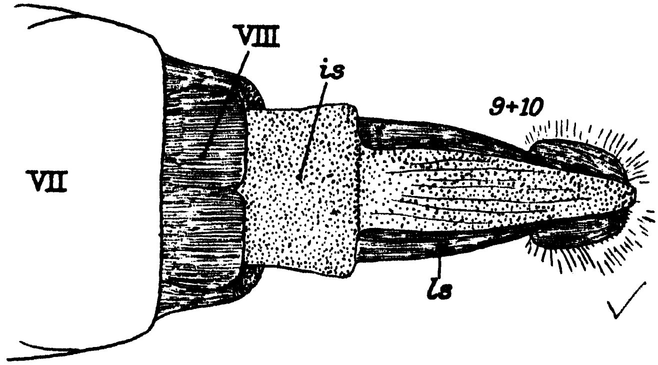


FIG. 92.

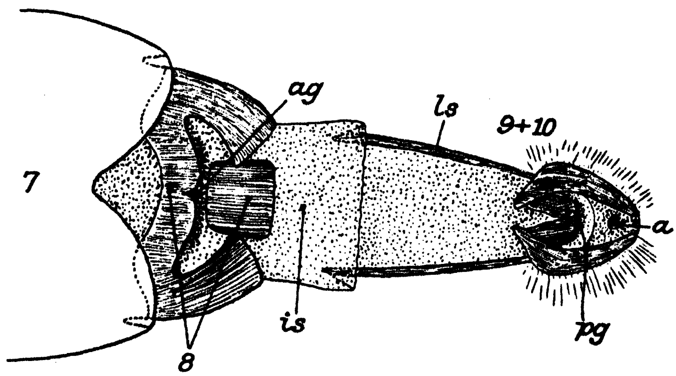


FIG. 93.

FIGS. 92 and 93.—Noctuid Moth ♀. Dorsal and ventral views of posterior end of abdomen, fully extended after being boiled in potash.

a = anus; *is* = intersegmental membrane; *ls* = lateral strut of fused segment 9 and 10 (9 + 10); VII and VIII = terga; 7 and 8 = sterna. Other lettering as in Fig. 91.

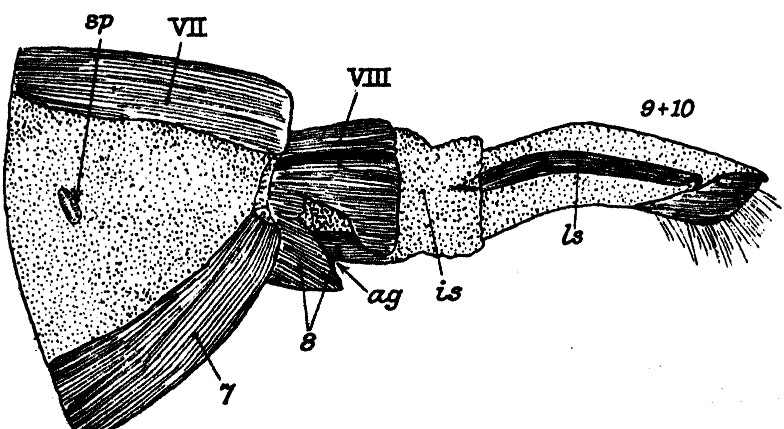


FIG. 94.—Noctuid Moth ♀. Lateral view of posterior end of abdomen, fully extended after boiling in potash. Lettering as in Figs. 91, 92 and 93.

(7) The Lepidopterous Larva or "Caterpillar"

Note. The following description is based upon the larva of the Noctuid, *Cucullia verbasci*, the Mullein Moth, but, in general, it will serve for most caterpillars.

Note the simple form and general similarity of all the segments behind the head. There are three thoracic and ten abdominal segments.

Examine the head and note the following points:

1. The epicranial sclerites and the median longitudinal suture between them.

Note the shape of the sclerites and the comparatively short suture. Where the edges of the plates separate behind is the "vertex" or "vertical triangle." On the anterior edges of the epicranials are the small 3-segmented antennæ. Note also the six ocelli on each epicranial plate.

2. Anteriorly, the frons and the adfrontal sclerites are wedged in between the epicranial plates. The frons is more or less triangular and the adfrontals are narrow plates between the frons and the epicranials, in this case not extending forward as far as the clypeus.

3. The narrow clypeus lies across the anterior border of the frons.

4. The labrum, more or less notched, according to the family and species of the caterpillar.

5. On each side of the labrum and projecting slightly in front of it can be seen the dark mandibles.

Make a drawing of the dorsal view of the head, noting a number of primary setæ and a few punctures on various parts. The position of these varies in different species and families and is of systematic importance. The complete list of these, not always present, is as follows:

Epicranials. 11. setæ on each plate; 1 puncture on each.
Adfrontals. 2 setæ on each and 1 puncture.
Frons. 1 pair of setæ; 2 frontal punctures.
Labrum. 6 pairs of setæ.
Clypeus. 2 pairs of setæ.

Ventral View

Note the close relationship between the maxillæ and labium, the two being fused together at the base.

1. The maxilla consists of cardo and stipes, the latter forming the main part of the structure. Upon this are two incomplete rings bearing the 2-segmented palp and a subgalea which bears a small galea and lacinia (the homology of the incomplete rings is doubtful; they may be parts of the stipes, but they can scarcely be regarded either as palpiger or as subgalea).

2. The labium consists of two separate cardines forming the "submentum," a large common stipes, the "mentum," and a common "subgalea" bearing the

palpigers and the labial ring or labium proper, from which projects the spinneret, the hypopharynx or true tongue.

Note the absence of ligula and paraglossæ (laciniæ and galeæ) (see Fig. 95).

The Thorax

Note the similarity between thoracic and abdominal segments; the former however, bearing the six true legs, segmented structures each bearing one apical claw.

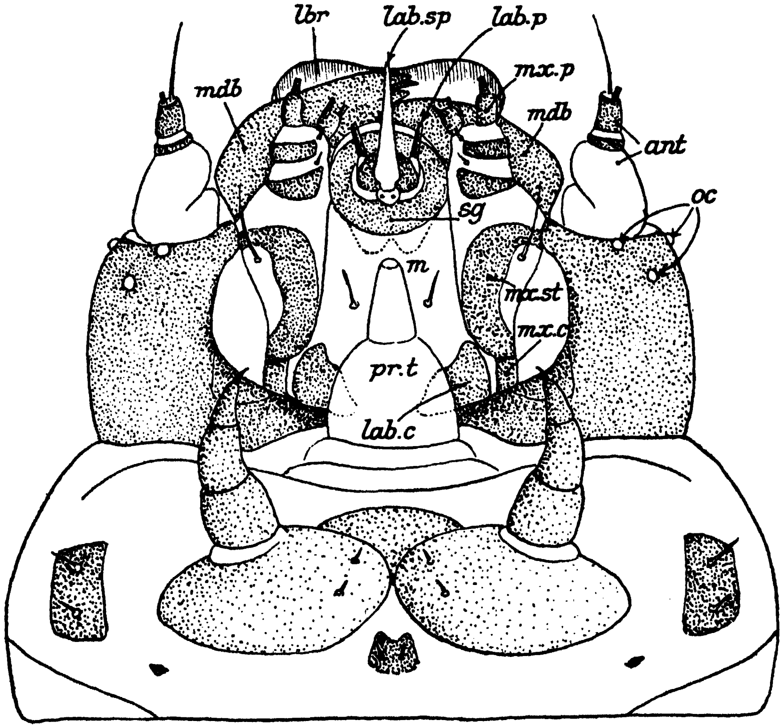


FIG. 95.—Caterpillar of Noctuid Moth. Ventral view of head and prothorax, after boiling in potash, showing the prosternal tube (*pr.t.*) everted. Note that, unlike most of the figures in this book, the hard chitinous parts are dotted while the membranous parts are plain.

ant = antenna; *lab.p* = labial palp; *lab.c* = cardo of labium; *lab.sp* = the spinneret; *m* = mentum (fused labial stipites); *lbr* = labrum; *mdb* = mandible; *mx.c* = cardo of maxilla; *mx.p* = maxillary palp; *mx.st* = maxillary stipes; *oc* = ocelli; *pr.t* = everted tube containing duct of repugnatorial gland; *sg* = subgalea of labium.

On the prosternum note a transverse slit. This is a pocket from which can be everted a "prosternal tube" containing a duct of a repugnatorial gland. This tube is shown extended in Fig. 95. It is peculiar to certain families and even to certain species within those families, e.g. Noctuids, Notodontids, Nymphalids, but similar glands, in other situations, are found in other families, e.g. Lycænidæ, etc.

One pair of thoracic spiracles only, the prothoracics, exists in the caterpillar.

No wings are visible, but a careful dissection of the sides of the meso- and meta-thoracic segments in a well-grown caterpillar would reveal the small pockets containing them.

The Abdomen. The 1st and 2nd abdominal segments bear no appendages,[1] but the next four segments may all bear each a pair of "prolegs."

In certain Noctuids the prolegs on segments 4 and 5 are absent or reduced and these larvæ, from their manner of walking, are called "Semi-loopers."

In the Geometrids, the prolegs on segments 4, 5 and 6 are absent and these larvæ are known as "Loopers."

No other segment bears these structures except the 10th (last) which bears a pair, sometimes called "anal prolegs" or "anal claspers."

Examine the proleg; note the primary hairs and important secondary (four or five in all) on the outer side at the base: the "subspiraculars."

Note the planta of the "foot" and the arrangement of the crochets or hooks.

Draw proleg and arrangement of crochets.

Note the eight pairs of abdominal spiracles, the last pair of which exists only as a scar in the pupa and disappears in the imago. Note the type of closing apparatus behind the spiracle (see Fig. 96) and compare with that in Dytiscus (Fig. 35).

Examine an abdominal segment and endeavour to make out the arrangement of the main setæ: "dorsals," laterals, "supra-spiraculars," "spiraculars" and sub-spiraculars (see Fig. 98, p. 160). (*N.B.*—In the work of determining genus and species, the setal arrangement is important, but only certain setæ are considered in running down a caterpillar to its family, as will be seen by reference to the key, pp. 161–165.)

Dissection

For dissection, a Goat Moth (*Cossus ligniperda*) caterpillar is convenient on account of its size. The caterpillar of the Mullein Moth (*Cucullia verbasci*) is very suitable, as the central nervous system, in freshly killed specimens, is dark red in colour and, even after some months in spirit, the colour remains.[2]

Pin the caterpillar down in the bottom of the dissecting-dish by pushing a pin through each side of the 1st abdominal segment and, having got it thus fixed, take a fine pair of scissors and, starting about the 8th abdominal segment, cut the

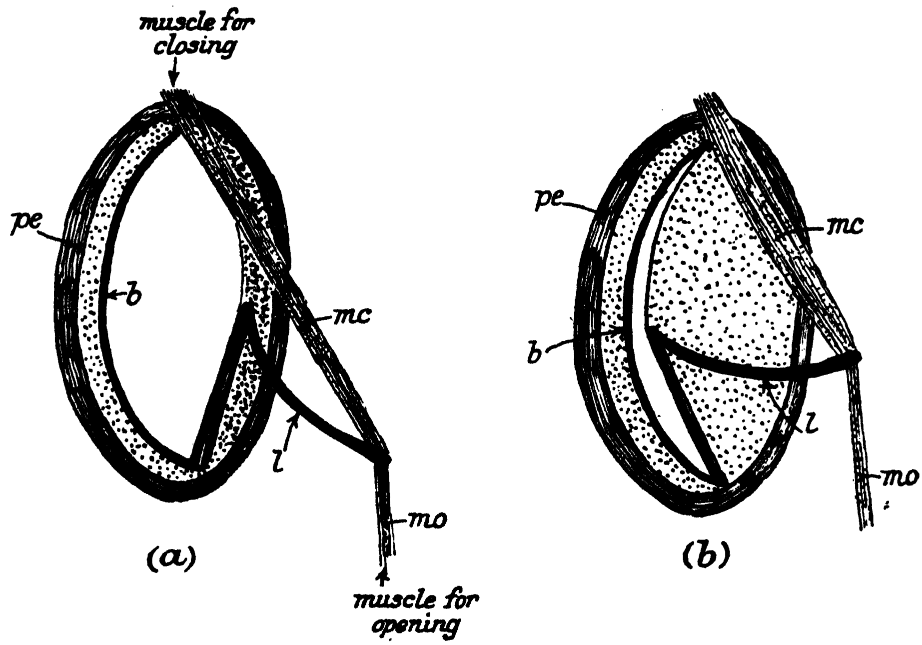
[1] In some caterpillars, e.g. Megalopygidæ, the second segment bears prolegs without crochets.

[2] To preserve caterpillars for future dissection, drop the living specimens into boiling water and continue to boil until they straighten out, which they will do after about four minutes. Remove them and dry very quickly by laying them upon blotting-paper or other absorbent and, while still hot, drop them into 70 per cent. alcohol.

A rapid method of preserving a caterpillar as a specimen, recommended by Rothschild and Jordan (*Sphingidæ*, 1, p. viii, footnote), *Novit. Zool.*, IX, 1904: Put the larva, after it is suffocated by benzine or chloroform, into a glass tube over a flame. The specimen will contract, then expand and burst in this expanded state. Let it cool and take out the larva.

skin, just to the side of the median dorsal line, forwards to the prothorax and then cut along the anterior margin of the prothorax on each side and spread out the sides and fix with pins. Now remove the original pins from the 1st abdominal segment and pin out the skin on each side all the way down the body, being careful not to damage any organs.

Note the elaborate musculature of the body: an outer layer of circular



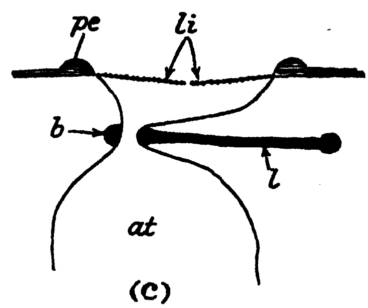


FIG. 96.—Caterpillar of Notodontid Moth. The closing apparatus behind the spiracle. (*a*) shows spiracle open, (*b*) almost closed.

mc and *mo* = the muscles which operate upon the lever (*l*) which pushes one side of the membranous tube against the other, see Fig. *c*, which shows a section of the spiracle; *at* = the atrium; *b* = the bow; *pe* = the peritreme of the spiracle; *li* = the lips of the spiracle.

muscles surrounding the complex arrangement of longitudinal bands of muscles.

The heart lies just beneath the median dorsal line in the abdomen and extends forward into the thorax and head as the aorta.

Otherwise, the most obvious structures are the alimentary canal and the gonads.

The Alimentary Canal runs the whole length of the body. The stomodæum or fore-gut is thin-walled and ends posteriorly, without any proventriculus, in

the mesenteron or mid-gut, which has opaque glandular walls, usually transversely thickened.

Along the sides of the mid-gut can be seen the fine malpighian tubules which run forward from the pyloric ring, a constricted area at the posterior end of the mid-gut and marking the commencement of the proctodæum or hind-gut.

The hind-gut enlarges behind the pyloric ring and is divided by a further constriction into an anterior part, the intestine, and a posterior part, the rectum.

Make out the points where the malpighian tubules enter the pyloric ring and note that there is only one duct on each side. Each duct divides and divides again, so that there are three long tubules on each side (see Fig. 97*c*). The gonads lie on the mid-gut in the 5th abdominal segment and are two small opaque bodies, each of which may be slightly constricted by more or less parallel grooves suggesting four bodies enclosed in a capsule. They may lie close together on each side of the median line or farther apart.

Free the Malpighian tubules from their attachments along the mid-gut and cut through the latter. Turn the posterior part of the gut out of the body over the posterior end.

Lift the anterior part, very carefully freeing all adhesions, which consist mainly of tracheæ, clear right forward to the posterior margin of the head and cut off, being careful not to damage anything else. Two long tubes are now exposed, lying on the floor and winding back and forwards. These are the true salivary- or silk-glands. In the metathorax these two glands taper off into a pair of salivary ducts which pass forward into the head.

On the side walls of the metathoracic segment there may be visible another pair of glands, fastened to the walls and even embedded in fat-body. From these there extend forward into the head a pair of ducts. These glands have been called salivary glands, the other pair already mentioned being distinguished as silk glands. As, however, the latter are homologous with the salivary glands of other insects, it is better to give this pair a distinct name and as they open at the bases of the mandibles, they are the "mandibular glands" (see Fig. 97*a*).

The Central Nervous System is now almost completely exposed. In the anterior part of the prothorax, the large subœsophageal ganglia are visible, followed closely by the 1st thoracic pair. The 2nd and 3rd thoracic ganglia are in their own segments, the latter followed closely by the 1st abdominal pair. The 2nd to the 6th abdominal ganglia lie in their respective segments and in segment 7 lie ganglionic masses, the 7th and the 8th, the latter giving off three pairs of nerves which pass backwards to the segments behind. Each ganglionic mass gives off lateral nerves in its own segment. Now remove the dorsal portion of the head. Insert the point of a pair of fine scissors into the large occipital foramen towards the side and cut forward to the uppermost ocellus and repeat the process on the other side. Very carefully lift the epicranium, freeing it from

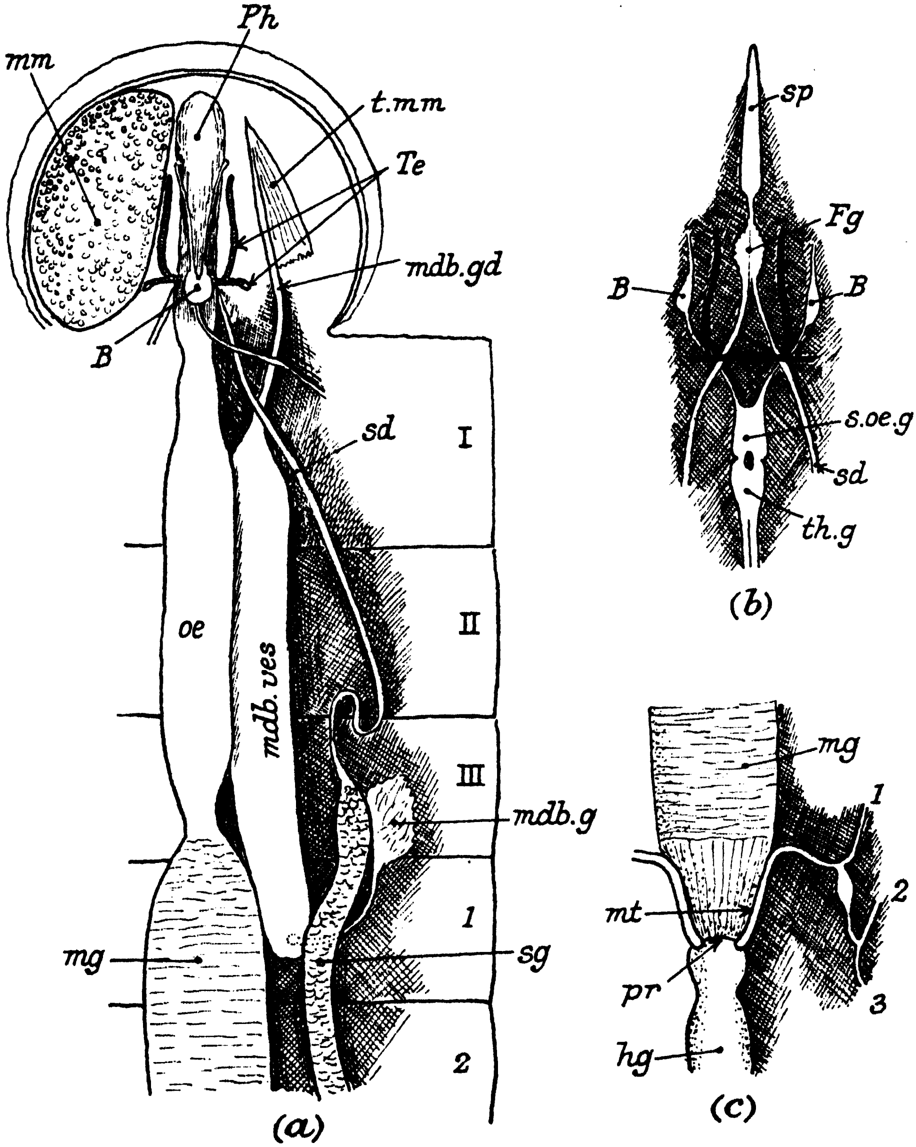


FIG. 97.—The Caterpillar.

(*a*) = dissection to show salivary duct, mandibular gland, etc.; *B* = brain; *mg* = mid-gut; *mdb.g* = mandibular gland; *mdb.gd.* = duct of mandibular gland, which runs down the tendon (*t.mm*) of the mandibular adductor muscle (*mm*); *mdb.ves* = vesicle upon duct of mandibular gland; *oe* = œsophagus; *Ph* = pharynx; *sd* and *sg* = salivary duct and gland; *Te* = tentorium. (*b*) = glands of Filippi, etc.; *sp* = spinneret; *BB* = brain cut in two longitudinally; *Fg* = glands of Filippi; *s.oe.g* and *th.g* = sub-œsophageal and first thoracic ganglia; *sd* = salivary duct. (*c*) = malpighian tubule (*mt*) dividing into three (1, 2, 3); *hg* = hind-gut; *pr* = pyloric ring.

muscle-attachments beneath, turn it right forward and pin down. Note the large muscles exposed, mostly belonging to the mandibles.

In the median line, gently separate the main masses and see the supra-

œsophageal ganglia or "brain" lying upon the aorta, which lies upon the pharynx. Note the two nerves passing forward from the brain, one on each side, and see the fine lateral commissures passing down and back on each side of the pharynx to the subœsophageal ganglia.

Very carefully and piece by piece remove the large mandibular muscles on one side and expose the vertically-placed flattened ligament of the adductor muscle. It will be seen that, from the ventral margin of this, there passes backward a duct which, if traced, will be found to lead to the mandibular gland, already mentioned. The opening of the duct is just at the base of the mandible.

Cut through the brain, separating the two ganglia and raise the pharynx, turning it completely forward. This exposes the tentorium, the internal head skeleton, which consists of two longitudinal parallel strips of chitin, one on each side of the gap, from which the pharynx has been removed and, posteriorly, a transverse bar. These are sometimes dark coloured and therefore easily recognized.

Now trace forward the two salivary ducts and note that they pass beneath the lateral commissures just in front of the subœsophageal ganglia and beneath the transverse bar of the tentorium, and they then come to lie side by side. Just in front of this a pair of glands, sometimes very small, at other times larger, lie upon them and communicate with them. These have been called the "glands of Filippi," although they were recognized long before his time, and they provide the coating material in which the two cores of the silken thread lie (see Fig. 97*b*).

Just in front of these glands the ducts unite and pass into the "filator," the apparatus which controls the flow of silk from the spinneret, and the filator lies in the base of the latter.

Preparation of Caterpillar for Minute Examination of "Skin"

This is more easily done with a specimen which has either been boiled for a few minutes or has been preserved for some time in spirit. (Noctuids or Geometrids are easily obtainable, as a rule.)

Insert one point of a fine pair of scissors into the anus and proceed to cut very carefully along the medio-ventral line until the head is reached.

(*a*) Either cut straight on through the head and back along the medio-dorsal line to the anus; or,

(*b*) as in some families (e.g. Lasiocampidæ) the head characters are of importance, cut round the margin of the head capsule until the medio-dorsal line is reached and then cut back along this to the anus.

The first method gives two similar halves while the second gives you one half with the head and the other without it.

Now boil the parts in strong potash until the transparent skin with only the tracheal trunk attached to it is left, free of all internal structures, which will have dissolved into sediment.

Carefully remove the tracheæ without pulling out the spiracles. Wash

the "skin" clear of potash and place in 70 per cent. alcohol for a few minutes, then in 90 per cent. and through absolute into oil of cloves. Now spread the "skin" carefully on a slide, the head, if complete, flat, so that all sutures and both sets of ocelli are visible, and place another slide on the "skin" and tie the two slides together with thread.

Place in xylol or in oil of cloves and leave for at least two or three days, after which, remove the cotton and the upper slide, and the skin will be found to have lost its springiness and will lie quite flat. It can now be permanently mounted under a cover slip.

Examine the slides so made with a view to seeing the characters of the families to which the caterpillars belong, working backwards in the key provided,

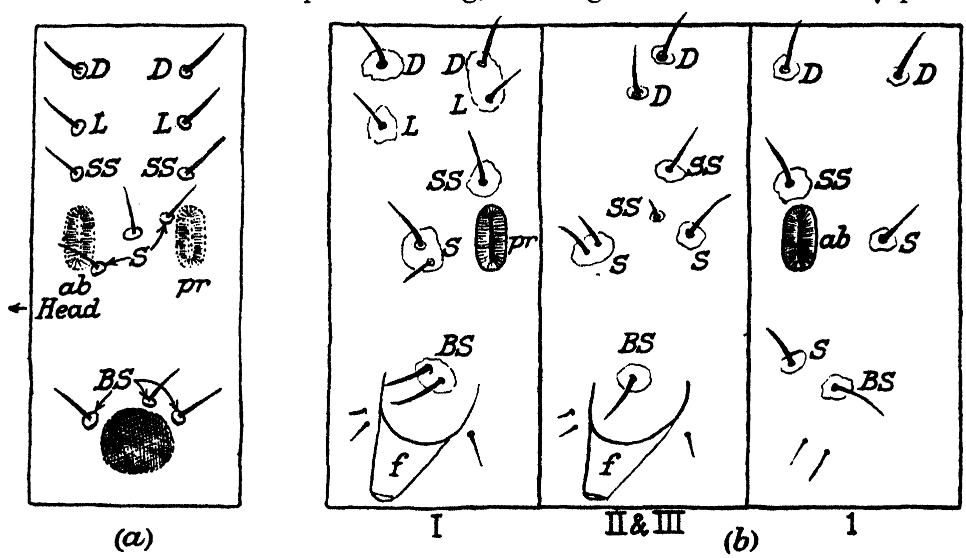


FIG. 98.—Caterpillar.

Setal plan (*a*) = a hypothetical segment showing the twelve primary setæ; *pr* = prothoracic; *ab* = abdominal position of spiracle; *BS* = subspiraculars; *D* = dorsals; *f* = leg; *L* = laterals; *S* = spiraculars; *SS* = supra-spiraculars.
(*b*) = setal plan of prothorax (I), meso- and meta-thorax (II and III) and first abdominal segment of full-grown caterpillar of *Cucullia verbasci*.

i.e. starting in the key at the family and seeing the characters mentioned and then going one stage back and so on. Slides of skins of named caterpillars of some half-dozen families should be handed out to the class: e.g. Hepialidæ, Psychidæ, Nymphalidæ, Arctiidæ, Noctuidæ, Geometridæ.

After these slides have been worked upon, unnamed slides should be provided and the class should work them out with the aid of the key.

(8) KEY FOR DETERMINING THE FAMILIES OF THE LARVÆ OF LEPIDOPTERA
Based upon S. B. Fracker's *Classification of Lepidopterous Larvæ*, 1915

This key is not meant to be an improvement upon the one on which it is based. It is rather a condensation and simplification in which various families, which

are obviously closely related and usually grouped together in super-families, are omitted, the determination only running to the super-family. The key is for the use of students learning the basis of systematic entomology and is regarded as sufficiently detailed for that purpose. The change in the nomenclature of the groups of body setæ is, however, regarded as an advance on the original, since the names now used suggest the position of the setal islands (see Fig. 98).

1. Spiraculars [1] on prothorax tri-setose; i.e. setæ 1, 2 and 3 present; never in the form of a verruca [2] or chalaza [3] and never unrecognizable on account of other setæ . 2
1. Spiraculars on prothorax not tri-setose, frequently bi-setose or may be in the form of a verruca or chalaza or unrecognizable on account of numerous hairs . . . 11

2. Crochets in a circle, penellipse [4] or in transverse bands 3
2. Crochets absent or in a pseudo-circle [5] or meso-series [6] . . . . . . Tineidæ

3. Subspiraculars [1] on the mesothorax uni-setose 4
3. Subspiraculars on the mesothorax bi-setose 10

4. Second dorsals [1] on segment 9 closer together than on any other abdominal segment, generally on the same pinaculum [7] or on adjacent ones. Spiracles always small, circular or nearly so . . . . Tortricidæ
4. Second dorsals on segment 9 at least as far apart as on other abdominal segments: never on the same or on adjacent pinacula. Spiracles of normal size and oval, or small and circular 5

5. Crochets in transverse bands; those on the anal prolegs in a single transverse row . 6
5. Crochets in uni- or multi-serial circle 7

6. Frons extending to about one-third of the distance to the vertical triangle . Cossidæ
6. Frons extending at least two-thirds of the distance to the vertical triangle Ægeriidæ (Sesiidæ)

7. Setæ 1 and 2 of the spiraculars on the abdomen adjacent 8
7. Setæ 1 and 2 of the spiraculars on the abdomen remote 9

8. Larvæ large borers. Mandibles large, extending far beyond the margin of the labrum. First dorsal [1] on prothorax closer to the mid-dorsal line than is the 2nd dorsal Cossidæ
8. Larvæ small leaf-feeders. Mandibles small. Second dorsal on the prothorax closer to the mid-dorsal line than is the 1st dorsal . . . . Tineidæ

9. Second setæ of the dorsals, laterals [1] and supra-spiraculars on the prothorax close together, just above the spiracle. Ocelli in two vertical rows of three each . Hepialidæ

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[1] For explanation of the terms "spiraculars," "subspiraculars," etc., see the text-figure 98.

[2] A verruca is a tuft of setæ projecting from a chitinous mound.

[3] A chalaza is a small thickened patch of chitin, either raised into a horn-like process (corniculum) bearing setæ or raised into one or more prominences, each bearing 1, 2 or 4 setæ.

[4] A penellipse is a series of crochets forming more than a semicircle and less than a circle in extent.

[5] A pseudo-circle is a full series of crochets on one half, the rest of the circle being completed by rudimentary crochets.

[6] A meso-series is a band of crochets extending longitudinally on the mesal side of the proleg; when curved, it may be a quadrant to slightly more than a semicircle in extent.

[7] A pinaculum is a small "island" of thickened chitin.

9. Second setæ of the dorsals, laterals and supra-spiraculars not close together on the prothorax and therefore not grouped just above the spiracle. Ocelli in a semicircle . . . Tineidæ

10. Long axis of the prothoracic spiracle vertical . . . . . . Thyrididæ
10. Long axis of the prothoracic spiracle horizontal . . . . Psychidæ

11. Prolegs and crochets absent . . . . Limacodidæ (Cochlidiidæ)
11. Prolegs and crochets present 12

12. Prolegs with not more than four setæ (three subspiraculars and a secondary seta), except when the crochets are in a multi-serial circle when there may be five. Body with neither tufted nor secondary setæ 13
12. Prolegs with at least five setæ, generally associated with several other sub-primaries. Crochets never in a multi-serial circle. Body may have tufted or secondary setæ 17

13. Crochets in a circle or penellipse or in transverse bands 14
13. Crochets in a pseudo-circle or a meso-series 15

14. Crochets uni-ordinal,[1] in a complete circle; body cylindrical. Mesothoracic subspiraculars uni-setose . . . . Alucitidæ (Orneodidæ)
14. Crochets bi-ordinal, except when the body is spindle-shaped and very fleshy and when the mesothoracic subspiraculars are bi-setose. (Crochets uni-ordinal in Galleria, the only genus) . . . . Pyralidæ

15. Meso- and meta-thoracic subspiraculars bi-setose; crochets uni- or bi-ordinal . . 16
15. Meso- and meta-thoracic subspiraculars uni-setose; crochets usually uni-ordinal but bi-ordinal in some forms . . . . . . Noctuidæ (including Agaristidæ)

16. Setæ small, borne upon minute papillæ. Crochets bi-ordinal Cymatophoridæ (Thyatiridæ, Polyplocidæ)
16. Setæ well developed, on chalazæ. Crochets uni-ordinal Arctiidæ (Lithosiinæ and Utetheisa)

17. Crochets uni-ordinal, except in certain Arctiids (Pericopinæ), where the main series is flanked on either side by a row of small crochets 18
17. Crochets bi-ordinal or tri-ordinal 35

18. Ventral prolegs, three or six pairs, not four 19
18. Ventral prolegs four pairs 20

19. Six pairs of ventral prolegs; those on segments 2 and 7 without crochets. Crochets usually in an angulated band. Verrucæ bearing large numbers of fine setæ Megalopygidæ
19. Three pairs of ventral prolegs; crochets not in an angulated band. Verrucæ with few setæ . . . . Arctiidæ (Nolinæ)

20. Verrucæ absent or reduced—or obscured by the development of secondary setæ . 21
20. Verrucæ, at least one just behind the subspiraculars, well developed and distinct and bearing many setæ; secondary setæ sparse or absent, except on the prolegs . . 29

21. Head rugose; ocelli on papillæ, the third very large. Suranal plate bifurcate Nymphalidæ (Satyrinæ (Agapetinæ))

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[1] Uni-ordinal, bi-ordinal, tri-ordinal = all in one, two or three sizes.

21. Head smooth or nearly so; ocelli sessile, the third normal. Suranal plate rounded . 22

22. Body very small, hemispherical; head minute, retractile; crochets uni-ordinal and in a complete circle. (Parasites on Fulgorids) . . . Limacodidæ (Epipyropinæ)
22. Body cylindrical; head normal size. (Non-parasitic forms) 23

23. Secondary setæ abundant, although they may be minute 24
23. Secondary setæ sparse or absent; primary setæ always distinct, although they may be small 26

24. Spiracles small, circular; ventral prolegs long and slender . . . Pterophoridæ
24. Spiracles oval, well developed. Ventral prolegs short 25

25. Labrum deeply notched, the notch with parallel sides and rounded bottom. Body often with tufts or pencils of setæ but never with horn-like processes. Anal prolegs as large as, or larger than, the ventral ones . . Noctuidæ (Acronyctinæ)
25. Labrum with acute notch, not parallel-sided. Body never with tufts or pencils but sometimes with horn-like processes. Anal prolegs reduced or modified, with few or no hooks . . . . Notodontidæ

26. Seta 1 of the subspiraculars at about the same level on abdominal segments 6, 7 and 8. Setæ very small. No humps, horns or cuticular processes . . Arctiidæ (Doa)
26. Seta 1 of the subspiraculars much lower on segment 7 than on 6 or 8 . . . 27

27. Suranal plate ending in an acute process. Anal prolegs absent. Crochets in a pseudo-circle . . . . Drepanidæ
27. Suranal plate rounded. Crochets in a meso-series 28

28. Body covered with minute cuticular processes. Dorsal hump on segment 9; no other outgrowths . . . . Arctiidæ (Dioptinæ)
28. Body not tuberculated, but outgrowths generally present . . . Notodontidæ

29. Eversible medio-dorsal glands on segments 6 and 7 . . Lymantriidæ (Liparidæ)
29. No eversible glands 30

30. Spiracles large and oval 31
30. Spiracles small and circular 34

31. Spiracular verruca 1 at about the same level on abdominal segment 7 as on 6 and 8 but, if lower, the mesothorax has only one verruca above the spiracular . . 32
31. Spiracular verruca 1 much lower on abdominal segment 7 than on 6 or 8, or fused with the spiracular verruca 2 33

32. Mesothorax with only one verruca above the spiraculars on each side . Syntomidæ
32. Mesothorax with two verrucas above the spiraculars . . . . . Arctiidæ

33. Crochets all in one series. Labrum with a deep parallel-sided notch. Mesothorax with two verrucas above the spiraculars . . . . Noctuidæ
33. Crochets in the main series flanked on each side by a row of smaller ones. Labrum with a rather wide, shallow emargination. Mesothorax generally with only one verruca above the spiraculars; the verrucæ conspicuous though without numerous setæ . . . . Arctiidæ (Pericopinæ)

34. Head small, retractile; prolegs short . . . . . Zygænidæ (Pyromorphinæ)
34. Head not retractile; prolegs long, slender, cylindrical . . . . Pterophoridæ

35. Setæ of the body primary or tufted: never numerous or secondary; several subprimaries on the venter or on the prolegs and sometimes rather numerous when the anal prolegs are absent or the others are reduced in number 36
35. Setæ of the body secondary, always numerous, at least on the prolegs; anal prolegs and four ventral pairs always present 41

36. Crochets in a complete circle 37
36. Crochets in a meso-series or a pseudo-circle 38

37. Dorsals 1 and 2 on the abdomen in the form of verrucæ. Spiraculars 1 and 2 on the abdomen remote . . . . . . Tineidæ (Hyponomeutinæ (Scythris))
37. Dorsals 1 and 2 on the abdomen, single setæ; spiraculars 1 and 2 on the abdomen adjacent . . . . Lacosomidæ (Pterophoridæ)

38. Suranal plate ending in an acute process; anal prolegs absent. Crochets in a pseudo-circle . . . . Drepanidæ
38. Suranal plate rounded; anal prolegs present 39

39. Four pairs of ventral prolegs, all well developed 40
39. Three anterior pairs of ventral prolegs reduced or absent . . . . Geometridæ

40. Prothorax and segment 8 of the abdomen with spiracles twice as large as those of other segments . . . . Epiplemidæ
40. All spiracles about the same size . . Cymatophoridæ (Thyatiridæ, Polyplocidæ)

41. Secondary setæ irregular in length, some ten times as long as others. Blunt, fleshy protuberances often present but no distinct verrucæ nor scoli [1] 42
41. Secondary setæ short and uniform or, if long and irregular, then verrucæ or scoli are present 43

42. Labrum deeply and acutely notched, the notch extending over two-thirds of the labrum and even continuing as a groove to the clypeus. Several medio-dorsal pencils of setæ often present. Blunt, fleshy protuberances never present. Eupterotidæ
42. Labrum obtusely notched, the notch usually not extending over more than one-half of the labrum, but never continued as a groove to the clypeus. Blunt, fleshy protuberances present . . . . Lasiocampidæ

43. Abdominal segment 8 generally without a medio-dorsal process or pair of processes or a scar; if not, the head, which is smooth, is produced into a high conical point. No other processes (scoli) on the abdomen. Crochets generally bi-ordinal . . 44
43. Segment 8 either without a medio-dorsal process or scar or else some or all of the last seven segments also have medio-dorsal scoli, or the head is conspicuously two-humped, usually having a pair of scoli or pointed processes. Crochets generally tri-ordinal 48

44. Body sphingiform,[2] without even rudimentary scoli or secondary setæ above the level of the prolegs 45
44. Body not sphingiform, always with at least rudimentary scoli 46

45. Segments showing six or eight annuli; prolegs not widely separated . Sphingidæ
45. Segments not showing annuli; prolegs widely separated . . . . Bombycidæ

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[1] Scolus. A spinous projection of the body-wall.

[2] Sphingiform. A cylindrical body with very short or no setæ and no other armature except a pointed process or horn on the 8th abdominal segment.

46. Ninth abdominal segment with a median spine or tubercle 47
46. Ninth abdominal segment without a median spine or tubercle . . Saturniidæ

47. Anal plate smooth. First dorsal scoli on the mesothorax but little longer than the abdominal scoli, which are often profusely branched . . Saturniidæ (Hemileucinæ)
47. Anal plate with at least a pair of small chitinous processes. First dorsal scoli on the mesothorax at least twice as long as the abdominal scoli 1 to 6. Scoli never profusely branched . . . . Ceratocampidæ

48. Crochets in a circle; lateral crochets about as well developed as the middle ones. Secondary setæ small or absent on the dorsal half of the body; never long and never on scoli 49
48. Crochets in a meso-series or a pseudo-circle; lateral crochets, when present, rudimentary. Long setæ and scoli sometimes present 50

49. Head much larger than prothorax; body tapering towards the ends. Crochets tri-ordinal and in a complete circle . . . . Hesperiidæ
49. Head partially retractile, smaller than prothorax; body cylindrical. Crochets bi-ordinal and in a complete ellipse . . . . Hesperiidæ (Megathymus) [1]

50. Meso-series of crochets interrupted or reduced at the middle and with a narrow spathulate fleshy lobe arising near the interruption. Head small. (Slug-like caterpillars.) Crochets tri-ordinal . . . . Lycænidæ
50. Meso-series of crochets without a fleshy lobe near the middle 51

51. No osmeterium [2] 52
51. Osmeterium present on the prothorax. When retracted, its presence is indicated by the presence of a groove in the medio-dorsal line. Crochets bi-ordinal in Parnassiinæ but otherwise tri-ordinal . . . . Papilionidæ

52. Scoli or fleshy filaments usually well developed on the body but, when reduced, large scoli are present on the head . . . . Nymphalidæ
52. No scoli or fleshy filaments on head or body 53

53. Suranal plate bifurcate at the tip, with two distinct processes Nymphalidæ (Satyrinæ (Agapetinæ))
53. Suranal plate rounded, entire 54

54. Crochets in a pseudo-circle. Head small. Setæ never on chalazæ . Erycinidæ
54. Crochets in a meso-series. Head normal or large 55

55. Head obviously larger than the prothorax. Crochets tri-ordinal, bi-ordinal or sometimes even uni-ordinal . . . . Nymphalidæ
55. Head not larger than the prothorax. Setæ usually on chalazæ. Crochets never uni-ordinal . . . . Pieridæ

[1] According to some authors, Megathymus is a genus of Castniid moths.

[2] Osmeterium, an eversible gland producing an odour, pleasant or otherwise.

(9) *DIPTERA*

The External Morphology of the Diptera

The "Blowfly" (*Calliphora erythrocephala*)

Head. Examine the head, front view, and note the large compound eyes between which is the epicranium or vertex. Note the absence of epicranial sutures.

At the apex of the epicranium note the three ocelli, arranged in a triangle with one angle forward. This is the "vertical triangle" and lies just in front of the "vertical margin," a narrow edge behind which the "occiput" descends vertically.

In the middle of the "face" is a deep more or less triangular depression, apex upward, the edge of the depression being the "frontal suture" or "facial ridge" or "ptilinal suture" and the depression itself, the frons, which is divided in the median line by a vertical ridge separating the two "antennal foveæ." The anterior limits of the frons and the identity of the clypeus are uncertain, though a sclerite on the dorsum of the basal half of the proboscis may be the latter (*vide* Imms, A. D., *Textbook of Entomology*, p. 593).

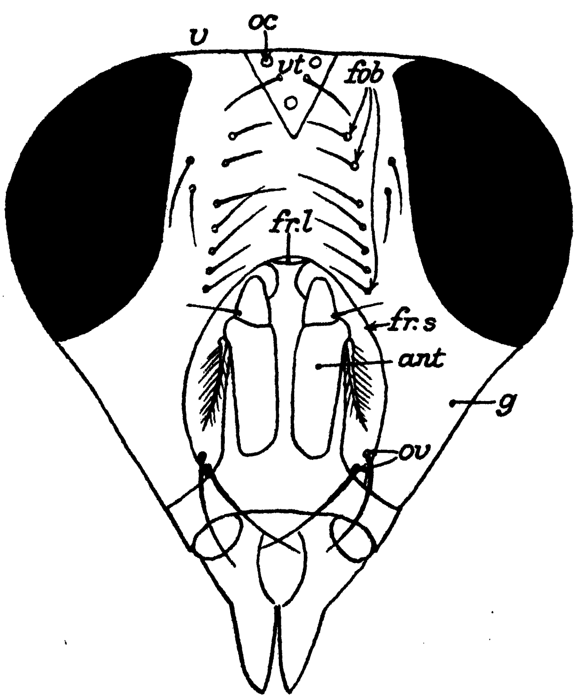

FIG. 99.—The Blowfly. Front view of head. *ant* = antenna; *fr.l* = frontal lunule; *fr.s* = frontal suture; *g* = gena; *fob* = fronto-orbital bristles; *oc* = ocellus; *ov* = oral vibrissæ; *v* = vertex; *vt* = vertical triangle, in which lie the three ocelli.

In the apex of the triangle formed by the frontal suture is a small crescentic plate, the "frontal lunule."

In the newly hatched Cyclorrhaph fly, the ptilinum can be projected from behind the frons, pushing the latter out from above. Thus the frontal (or ptilinal) suture is the edge of the "door" which opens to allow the ptilinum to expand, but, as the latter is merely a fold of the head skin, the suture is really a narrow slit. After the fly has been out of the puparium for a short time, the ptilinum cannot again be exserted and only the suture remains to indicate its previous existence. Thus it is characteristic of the Cyclorrhapha (see Fig. 99). (Compare with a Tipulid or a Tabanid fly.)

The proboscis consists of a basal piece and an apical part, at the free end of which are two large lobes, the "labella," the bases of the absent labial palps. The basal piece, which is probably an extended part of the head, when at rest lies backwards in a groove on the underside of the head, the maxillary palpi lying forwards along each side of it. The apical part of the proboscis lies forwards in the groove and the labella, when at rest, are folded together.

The Antenna. Compare the antenna of a Tipulid, a Tabanid and a Muscid fly, as examples of three types of antenna in the Diptera. The Tipulid, an example of the Nematocera, has filamentous antennæ; the Tabanid, an example of the Brachycera, has a shortened and thickened antenna, the apical segments tending to taper off into a "style"; the Muscid, an example of the Cyclorrhapha, has a 3-segmented antenna, the apical segment being compound and bearing a dorsal "arista." (*N.B.*—The types of antenna are not entirely characteristic of the groups to which these examples belong; thus, many Brachycera have 3-segmented antennæ.)

The arrangement of the setæ upon the head are of systematic importance but mainly within the families, the fronto-orbital bristles and the oral vibrissæ being the only groups used in the key for determining the families of Diptera [1] (see Fig. 99).

Thorax. The prothorax is only to be seen by removing the head when, immediately surrounding the gap, will be seen five sclerites, i.e. two pronotals, two episternals and one sternal. Behind each episternal is a larger epimeron. (The prothorax in the Nemocera is slightly larger, appearing as a small collar.)

The metathorax is also reduced to a small part behind the mesothorax, which is the main structure and the only segment visible from above.

The mesonotum is crossed by two depressions, the anterior one, faintly marked in the middle, running just in front of the bases of the wings, is the "transverse suture," and separates the prescutum from the scutum. The posterior one is well marked and cuts off the more or less semicircular scutellum. At the anterior angles of the mesonotum note the small bosses known as the "humeral callus." Immediately behind the ends of the transverse suture is a small "pre-alar callus," while at the posterior angles of the scutum are the "post-alar callus" protuberances. The scutellum is connected with the scutum on each side by the "scutellar bridge." The groove along each side of the mesothorax, just above the bases of the wings (on the inner margin of which there are, in many flies, characteristic bristles), is the "supra-alar groove."

On each side of the scutellum note the scale-like lobe of the wing, the "calyptron" or "squama." The size of the calyptron separates the two large groups of the Muscoidea, the Calyptratæ, in which this lobe is large and conceals the halter, and the Acalyptratæ, in which the lobe is small or even absent. The Blowfly belongs to the Calyptratæ (see Fig. 100).

[1] Balfour-Browne, F., *Keys to the Orders of Insects*, Cambridge University Press, 1920.

Note the halteres, one beneath each calyptron, and remember that they are metathoracic structures and are modified wings.

Thorax. Lateral view. Turn the fly on its side and note that the prothoracic sclerites are again barely visible, merely showing as small projections

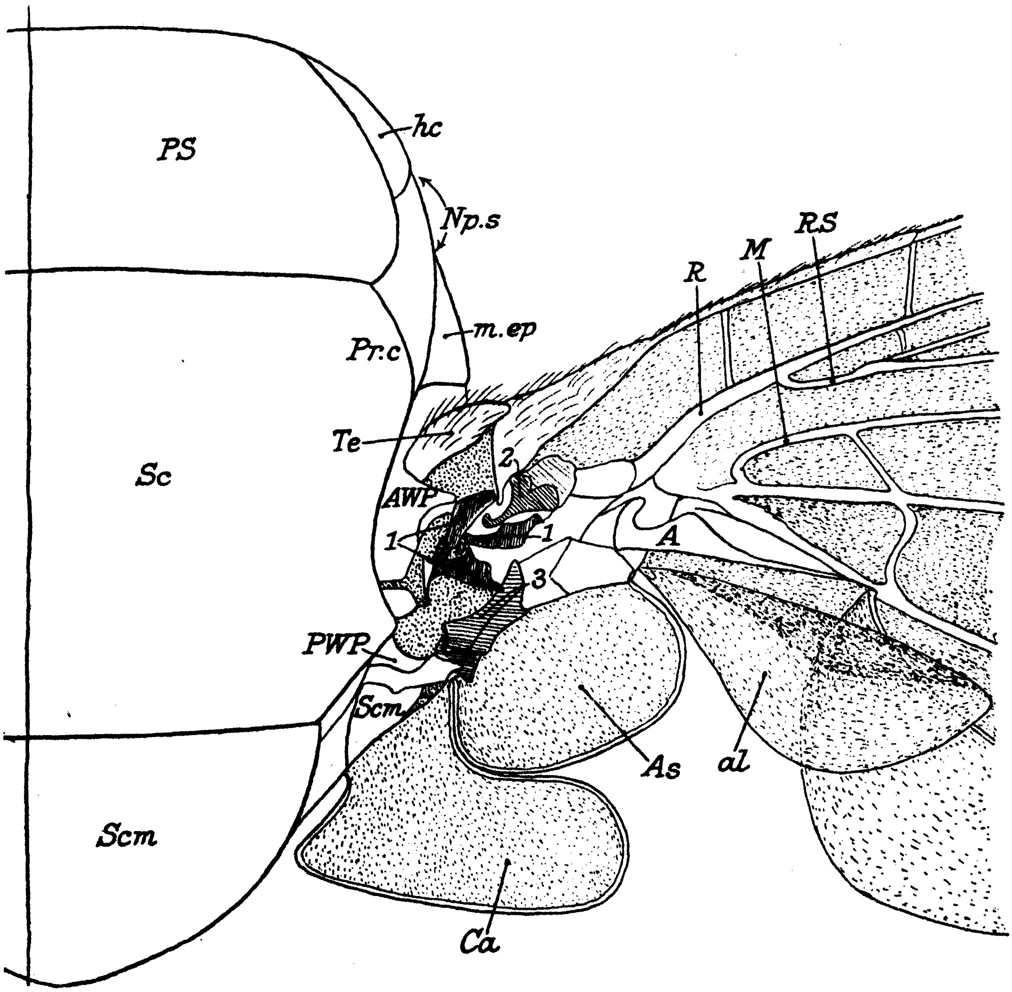

FIG. 100.—The Blowfly. Dorsal view of mesothorax and wing connections.

A = base of anal vein; *al* = alula; *As* = antisquama; *AWP* = ant. notal wing process; *Ca* = calyptron; *hc* = humeral callus; *M* = median vein; *m.ep* = episternum of mesopleuron; *Np.s* = "notopleural suture"; *PS* = prescutum; *Pr.c* = prealar callus; *PWP* = post. notal wing process; *R* = radius vein; *RS* = radial sector; *Sc* = scutum; *Scm* = scutellum; *Te* = tegula; 1, 2 and 3 = the axillary sclerites.

on the anterior end of the mesothorax and just above the 1st coxa, which, of course, is prothoracic. Remove the anterior legs to see this and make sure that you remove the coxæ.

In the meso- and meta-thorax of Cyclorrhaph flies, the sclerites have not yet

been satisfactorily homologized and a terminology, due to Osten Sacken, has been adopted by Dipterologists, which is not intended to suggest homologies.

The difficulty seems to be confined to the mesothorax, where the episternum of the pleuron and the sternum are fused, the transverse suture which exists cutting across the episternum. Further, the epimeron of the segment is divided up by several sutures. The limits of the segment are, however, quite clear (see Fig. 101*a*).

The episternum of the metathorax is also fused with the sternum of its segment, but the pleural suture is easily recognized, as is also the small epimeron

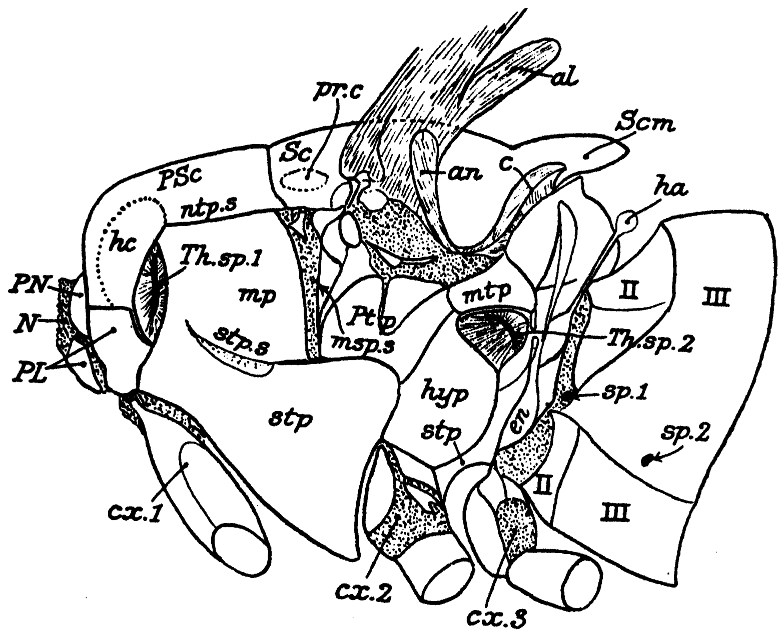

FIG. 101.—Muscid Fly. Lateral view of thorax and ant. abdominal segments, after boiling in potash.

al = alula; *an* = antisquama; *c* = calyptron; *cx.*1, 2, 3 = the three coxæ; *en* = epimeron of metathorax; *ha* = halter; *hc* = humeral callus; *hyp* = hypopleuron; *mp* = mesopleuron; *msp.s* = mesopleural suture; *mtp* = metapleuron; *N* = "neck"; *ntp.s* = notopleural suture; *PL* = pleuron of prothorax; *PN* = pronotum; *pr.c* = pre-alar callus; *PSc* = prescutum; *Ptp* = pteropleuron; *Sc* = scutum; *Scm* = scutellum; *sp* = spiracle; *stp* = sternopleuron; *stp.s* = sternopleural suture; *Th.sp.*1 and 2 = thoracic spiracles.

behind it. Fig. 101 shows Osten Sacken's nomenclature, and it will be seen that his "mesopleural suture" is the pleural suture according to the usual rule. The sternopleuron of the mesothorax is the sternum fused with part of the episternum. The pteropleuron, hypopleuron and metapleuron are the three main parts of the large epimeron.

Note that the 1st spiracle, owing to the shape of the mesonotum, with its bulging humeral callus, appears to be in the mesothorax but is actually between the prothoracic pleuron and the meso-episternum, as it should be (see Fig. 101). Within the families of the Order, the setal arrangement or "chætotaxy" of the thorax

is of extreme systematic importance, but it is not used in separating the families.

The Wing. Fix the specimen by means of a pin through the mesonotum and spread out the right wing. Note the form of the wing, with three large posterior lobes, the calyptron or squama next to the body, the antisquama and the alula. Immediately overlying the base of the wing on its anterior border is the small hairy tegula, which moves freely.

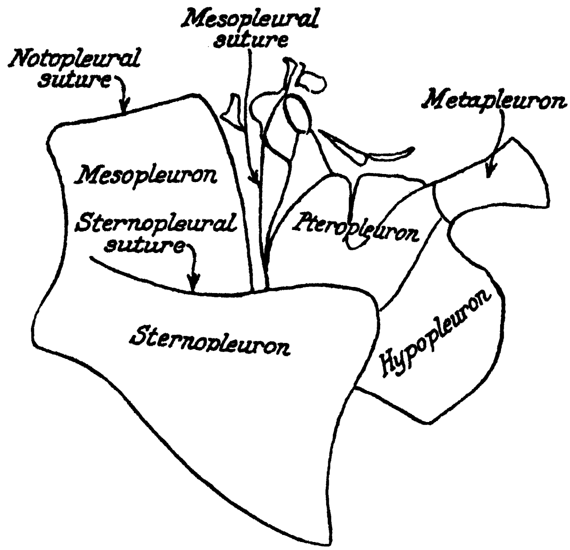

FIG. 101*a*.—Side view of the mesothorax (from Fig. 101) to show its limits.

Note the axillary membrane, and by the rules mentioned in connection with the Noctuid Moth (see p. 146) make out the axillary sclerites, which are not easy to determine (see Fig. 100, *supra*).

Examine the venation, for a description of which see pp. 111, 112.

Compare the Muscid wing with that of a Syrphid (Eristalis) and with that of a Tipulid.

The Abdomen. There has been considerable difference of opinion as to the number of abdominal segments in Diptera and as to their homologies. In the blowfly, for instance, there are four *visible* terga and four obvious sterna in both sexes (see Fig. 102). An examination will show that these terga and sterna correspond and that, in front of the first visible segment, is another small one, and there is no direct evidence of any other anterior segment. Some authors have recognized this small segment as the 1st abdominal while others regard the true 1st as having become absorbed in the metathorax, the view adopted here, for the reason given below.

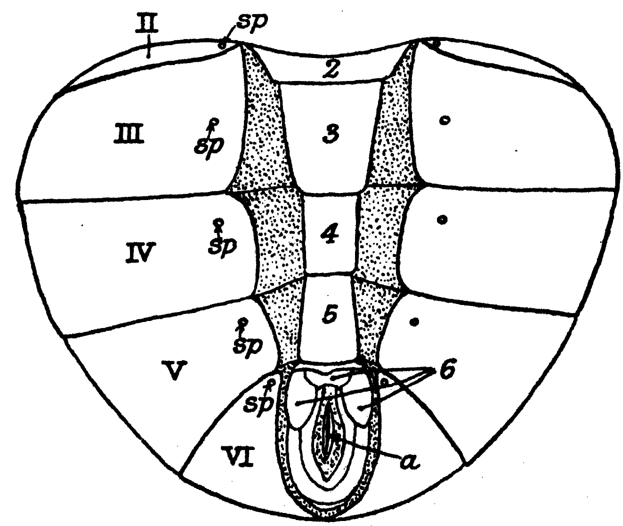

FIG. 102.—Blowfly. Ventral view of pre-abdomen. *a* = anus; *sp* = spiracle; Roman numerals = terga; Arabic numerals = sterna.

The apex of the abdomen, usually known as the "post-abdomen," the visible part being the "pre-abdomen," is telescoped within the anterior part and, again, there is a difference of opinion as to what segments exist.

It will now be best to deal separately with the sexes, as the female possesses a definite 10th segment, while in the male the 9th and 10th are fused together.

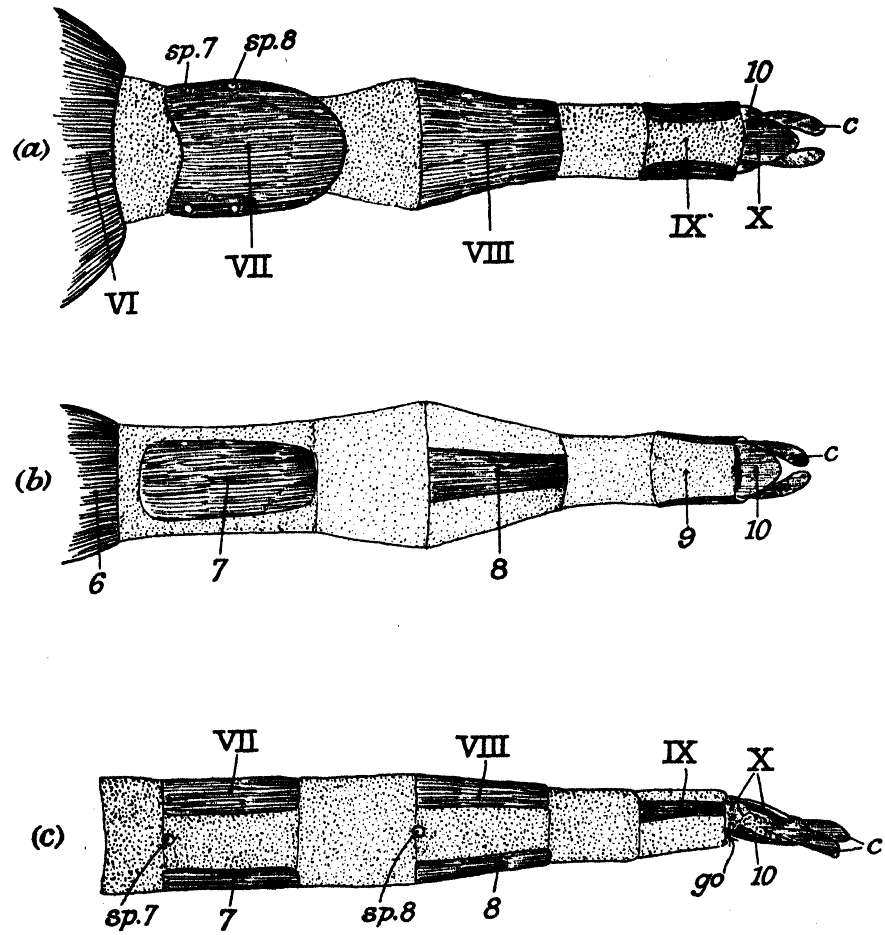

FIG. 103.—(*a*) and (*b*) are dorsal and ventral views of the post-abdomen of the female blowfly; (*c*) is a side view of the post-abdomen of Eristalis sp. ♀.
c = cercus; *go* = gonopore; *sp* = spiracle; Roman numerals = terga; Arabic numerals = sterna.

The female post-abdomen. After boiling the abdomen in potash, it is easy to extend the telescoped segments by pulling gently on the apex with a pair of forceps. This will reveal the existence of four segments, the two nearest to the pre-abdomen being complete with tergum and sternum, the next having two broad dorso-lateral chitinous strips and being otherwise membranous and the last segment again being complete with tergum and sternum and bearing a pair

of appendages called "styles," which are the true cerci. The anus lies in this segment.

It is generally agreed that the female gonopore in Diptera is situated behind the 9th sternum, and it is therefore easy to identify the incompletely-chitinized segment as the 9th. This necessitates one of two assumptions, either that one of the two preceding segments is really two segments fused together or that the 1st abdominal segment is absent in the Diptera. The first assumption is *apparently* supported by the fact that, in this type, the 1st segment of the post-abdomen has two pairs of spiracles, but it is dispelled by an examination of other types, e.g. Eristalis (Syrphidæ), where this segment and the following have each one pair of spiracles (see Fig. 103). The second assumption is definitely supported (1) by the fact that, in all the other higher Orders of insects, the 1st abdominal sternum is absent or membranous, whereas the apparent 1st abdominal segment is here, and elsewhere, e.g. Eristalis, complete; and (2) by the fact that, if the 1st segment exists, then in some types, e.g. Eristalis, the 7th segment bears the last pair of spiracles and the gonopore opens behind the 8th sternum.

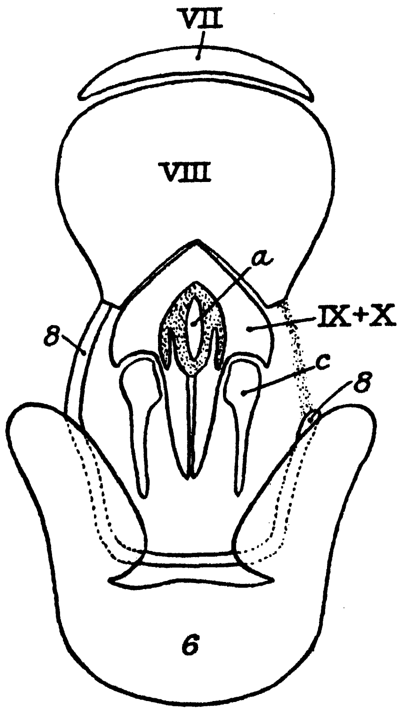

FIG. 104.—Blowfly ♂. End view of post-abdomen with parts somewhat expanded after boiling in potash.

a = anus; *c* = cercus; Roman numerals = terga; Arabic numerals = sterna.

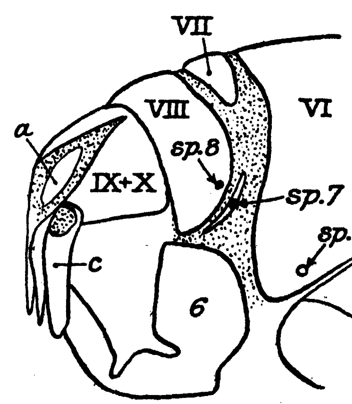

FIG. 105.—Blowfly ♂. View of right side of the end of the post-abdomen.

sp = spiracle. Other lettering as in Fig. 104.

We may, therefore, definitely adopt the view of Berlese (1909) and others that the 1st abdominal segment is entirely absent.

The male post-abdomen. This is so packed into the end of the 6th segment that but little can be seen of it until it has been boiled in potash and

drawn out, although the 6th sternum, deeply split in the median line, is recognizable (see Fig. 104). The extended portion exhibits a 7th segment consisting largely of membrane, the tergum being recognizable as a small narrow dorsal sclerite. The spiracle of this segment lies in a small chitinous area, well removed ventrally from this dorsal sclerite. The 8th tergum is well chitinized and its spiracle can be seen very near that of the 7th segment. Behind the 8th tergum is the last tergum, recognizable by the median dorsal anus and by the two pairs of processes projecting backwards from it, the outer pair being the cerci or styles. This is a compound segment because it carries the sternum which bears the genital armature, which is the 9th, and yet the tergum corresponds very well with the 10th tergum of some other types, e.g. Eristalis, where there is a large separate 9th tergum as well. The 8th sternum can be seen by examining the left side of the 8th tergum (see Fig. 104). It is an incomplete chitinous loop extending round the ventral side and partly up the right side but not again reaching the tergum. The 9th sternum bears the highly complex ædeagophore (see Figs. 105, 106 and 107), as to the homologies of which there seems to be no clear understanding. Edwards [1] says that "it is very difficult to homologize the parts

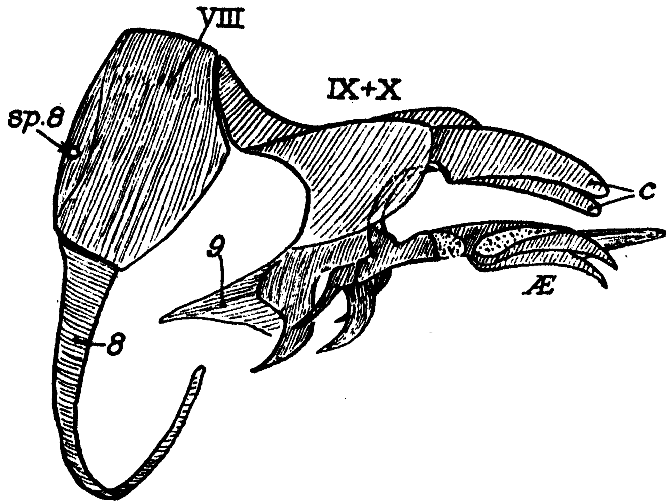

FIG. 106.—Blowfly ♂. View of left side of the end of the post-abdomen with ædeagus extended, after boiling in potash.

Æ = ædeagus. Other lettering as in Fig. 104.

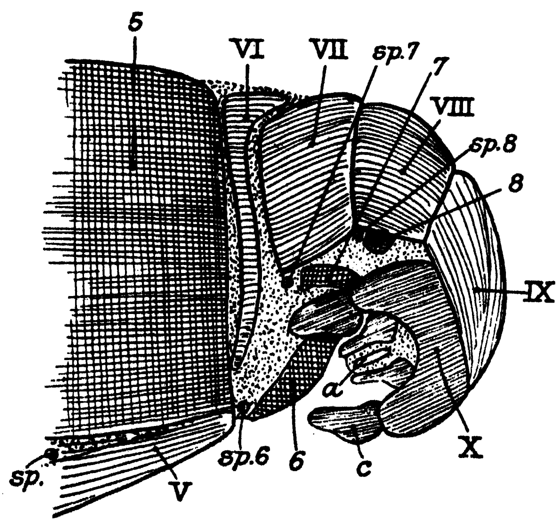

FIG. 107.—Eristalis sp. ♂. The post-abdomen extended from the pre-abdomen, after boiling in potash. Note the twist of the segments, such that the anus is on the right side of the body.

a = anus; *c* = cercus; *sp* = spiracle; Roman numerals = terga; Arabic numerals = sterna.

[1] Edwards, F. W., "The Nomenclature of the parts of the Male Hypopygium of Diptera Nemocera, with special reference to Mosquitoes," *Ann. Trop. Med. and Parasit.*, XIV, 1920, 21, p. 26.

of the Nematocera with those of the Cyclorrhapha, and it is beyond the writer's intention and competence to do so." It is therefore scarcely necessary to state that the matter is beyond the limits of this book.

(10) Types of Dipterous Larvæ

(1) **The larva of Tipula** (the Crane-fly or Daddy-long-legs). Larva known as a "Leather-jacket."

The fly belongs to the group Orthorrhapha: Nematocera.

Note the fact that the head-capsule is retracted within the prothorax and that, although the body is ringed, it is difficult to determine the limits of the segments. A careful examination, however, will reveal the existence of scattered short black spines and a ventral view will show that these are arranged in series of four across each segment. It can thus be seen that there are three rather narrow thoracic rings, a narrow 1st abdominal and six wide segments, the 8th being narrow ventrally but very wide dorsally, and including the spiracular cavity. This cavity is surrounded by six processes, two dorsal, two lateral and two ventral. The 9th and last segment is the anal tube. In some species of Tipulid larvæ it is not so easy to recognize the segments, but the posterior spiracular segment is always the 8th. In order to see the head, boil the larva in strong potash, having first punctured the body in two places with a needle, one near the head and the other near the posterior end, to prevent it bursting. Through the cleared skin the head-capsule will be visible.

Note that it is more or less complete, except that the posterior end is open. An attempt to make it protrude from the prothorax will show that only a small part of it can be exserted.

This is one of the more primitive types of Diptera and, in the process of evolution of this Order, the larval head has gradually become reduced. Compare with the so-called acephalous larva, typical of the Cyclorrhaph flies, or examine a series of slides or specimens of larvæ of some or all of the following families, showing stages in head reduction: Culicidæ, Mycetophilidæ, Chironomidæ, Ptychopteridæ, Bibionidæ, all examples with a complete head and known as "eucephalous." Tipulidæ, Leptidæ, Stratiomyiidæ, three examples of the Orthorrhapha Brachycera, a group with reduced heads, incomplete posteriorly, a type known as "hemicephalous." Syrphidæ and Muscidæ, both examples of the Cyclorrhapha, the former with more head remnant than the latter, but both belonging to the type known as "acephalous."

(2) **The larva of Calliphora** (the Blowfly). Larva known as a "maggot."

The fly belongs to the group Cyclorrhapha: Schizophora.

Note the form of the larva, tapering towards the anterior end and obliquely truncate at the posterior end. The body consists of twelve segments, three thoracic and nine abdominal, the last or anal segment being small and looking

as if it were an appendage of the eighth. (Compare the 10th segment in many Coleopterous larvæ.)

N.B.—This view as to the number of segments is in agreement with that of several authors (see Gordon Hewitt, *The House-fly*, 1904, pp. 115, 116), but the explanation differs. Hewitt described the posterior spiracles as being on the 12th body segment, omitting the head remnant, which places them on the 9th abdominal segment. Brauer recognized twelve post-oral segments, but regarded the last as made up of two. This would place the spiracles on the 9th or 10th abdominal segment. No other insect has any spiracles behind the 8th segment and therefore there is no reason to believe that the Cyclorrhaphous Diptera are exceptions.

Note the almost complete absence of head, of which only a remnant is visible, projecting from the prothorax. Hence the description of the larvæ as "acephalous maggots." Note the absence of legs which never occur in Dipterous larvæ.

The Head. Examine the head remnant and note the mouth-hooks, "crochets" or "mandibular sclerites," projecting from beneath a pair of prominences. These prominences have been called "oral lobes," and each bears two small papillæ, the "optical tubercles." On the other hand, these papillæ have been described as representing a pair of antennæ and a pair of maxillary palps. In some Cyclorrhaph larvæ, a pair of minute papillæ exist beneath the mouth-hooks and these have been described as labial palps. The form of the mouth-hooks varies in different groups of Cyclorrhaphs and, as a rule, they are sharply pointed in carnivorous forms and toothed in phytophagous ones.

The Body. Only two pairs of spiracles exist, and one of these is on the prothorax and the other on the truncated face of the 8th abdominal segment. The prothoracic pair are elongate, pale yellow structures, with a series of slightly-projecting pores arranged along a flattened edge. The abdominal pair are typical cyclorrhaphous spiracles with three slit-like openings to the vestibule or atrium within. The cyclorrhaph larva is metapneustic during the first instar and becomes amphipneustic at the first moult.

Note the series of short spines arranged in rings, broader ventrally and narrower dorsally, surrounding the body. These are for the purpose of assisting in locomotion.

General Points.

1. The absence of colour in the larva suggests that it does not live in the open.

2. The shape, with a small anterior end, suggests that it is adapted for boring or pushing its way through something.

3. The position of the posterior spiracles, which are the more important ones for respiration, situated upon a flat area, suggests that the larva belongs to a group living in liquid or in semi-fluid surroundings, the flat area being brought to the surface.

The Cephalo-Pharyngeal Skeleton. Cut off the anterior third of the larva and boil in strong potash. Remove the cephalo-pharyngeal skeleton and recognize the parts: the "pharyngeal sclerite," the largest piece; the "hypostomal sclerite," a small H-shaped sclerite just in front of the first; the "dentate sclerite," a minute piece between and ventral to the bases of the mouth-hooks.

(11) *HYMENOPTERA*

THE EXTERNAL MORPHOLOGY OF THE HYMENOPTERA

The Wasp (Vespa sp.).

General Features. Note that the head is attached to the thorax by a neck which allows it a very free movement. The mid-body, which appears to be the thorax but which really consists of thorax and 1st abdominal segment, and is called the "alitrunk," is connected with the hind-body by a narrow waist, the "petiole," which is the anterior part of the 2nd abdominal segment. All those Hymenoptera with a waist are described as "petiolate" and belong to the group Hymenoptera Petiolata, those without a constriction being the H. Sessiliventres. In the wasp the petiole is smooth, but in ants it has one or more dorsal processes, known as "nodes" or "scales," a character which distinguishes Ants or Heterogyna from other H. Petiolata. Examine, under the microscope, some of the hairs taken from the "shoulders" of the wasp and compare with some taken from a similar situation in a Hive-bee or a Humble-bee. Note that, in the wasp, they are simple and, in the bee, they are branched (plumose) or "compound," a character which distinguishes the two groups of wasps, Vespoidea and Sphecoidea, from bees, Apoidea.

The Head. Examine this from the front and note that the "face" is bounded on each side by the large compound eyes. The upper part of the face is the "frons," bounded below by a suture in the line of the antennæ, below which is the "clypeus."

On the upper part of the head, the "vertex," are three "ocelli" or simple eyes. The epicranial plates are not marked off from the frons. Below the clypeus is a small, less strongly chitinized "labrum."

Below the clypeus and labrum the "mandibles" complete the outline, the right one overlapping the left.

The antennæ consist of twelve segments, since the specimen provided is almost certainly a female, either a queen or a worker. Note that in almost all Aculeate Hymenoptera the antennæ of the female consist of twelve and those of the male of thirteen segments. The basal segment bears a ball-joint fitting into a socket on the head and is the "scape." It bears the "flagellum," composed of a short 1st and a long 2nd and nine more or less similar segments. (Note that the proportionate lengths of the basal antennal segments is an important systematic character in some of the Hymenoptera.)

Behind the vertex, the head is composed of the "occipital region" and, on each side, behind the eyes and extending down to the base of the mandibles, is the "gena" or cheek.

Examine the ventral aspect of the head and note the large excision in which lie the bases of the mouth-parts. These visible parts consist, on each side, of the stipes of the maxilla and, in the middle, of the mentum or fused stipites of the labium, which bears at its anterior margin a pair of 4-segmented labial palpi.

By pressing forward the mouth-parts, the cardines of the maxillæ become visible, two small triangular sclerites, their apices towards the stipites and their bases projecting outwards and into the head to their points of insertion. Thus the cardines, in a state of rest, stand more or less vertically, but can turn on their points of insertion so as to allow the mouth-parts to project forward. (The movement of the mouth-parts is much greater in the bees, e.g. Apis or Bombus, and the mouth-parts of one of these types should be compared with those of the wasp from this point of view.) (See *ante*, p. 64 and Fig. 42.)

The Alitrunk or Mid-body. Note the close fusion of the segments composing this mass in which, excepting certain sclerites associated with the wings and anterior legs, all the parts are ankylosed.

Dorsal Aspect. Note the large black plate extending forwards, almost to the anterior margin of the thorax, and backwards to behind the insertion of the wings. This is the main part of the mesonotum. On each side of this and overlapping the bases of the wings, is a small yellow plate, the tegula (or "parapteron" of some authors [1]).

Immediately in front of the tegula and extending forward, bounding the mesonotum on each side, is the pronotum. Pull the head forward to see the extension of the pronotum round the anterior edge of the mesonotum.

(*N.B.*—The relationship between the tegulæ and the pronotum is of great importance systematically. Examine a Hive-bee or a Humble-bee, first removing the hairs from the shoulders, and note that, in it, the pronotum does not extend back to the tegulæ. The Apoidea, Sphecoidea and the Chalcidoidea are all alike in this character while the Cynipoidea, Ichneumonoidea and the Proctotrypoidea are like the Vespoidea in having the pronotum extending to the tegulæ.) (See Fig. 108.)

In many Hymenoptera the mesonotum is divided longitudinally by grooves into a median and two lateral pieces, these latter being known as the "parapsides" of the mesonotum and this is faintly traceable in the wasp. Behind the main part of the mesonotum is a more or less semicircular sclerite, the scutellum of the mesothorax. Recognize its posterior limits by the axillary

[1] The name "parapteron" has also been applied to some small sclerites beneath the wing, better known as "epipleurites," those in front of the pleural-wing-process being "basalares," those behind being the "subalares."

chords running out on each side to the hind margin of the wing. Behind this lies the metanotum with a blunt point projecting backwards. Behind the metanotum is the propodeum or median segment, the true 1st abdominal segment, on each side of which can be seen the narrow curved slit of the spiracle of the segment.

Lateral Aspect.

(1) The prothorax. Note that on each side of the "neck" is a double sclerite which extends round to the ventral side, so that the two pairs almost

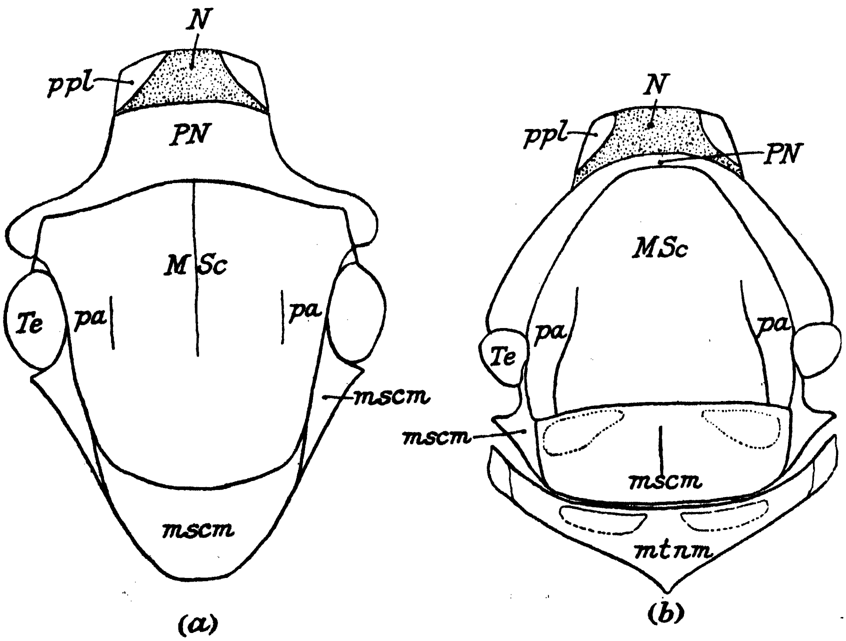

FIG. 108.—(*a*) Bombus Sp., dorsal view of pro- and meso-thorax; (*b*) Vespa Sp., dorsal view of pro-meso- and meta-thorax.

MSc = scutum of mesothorax; *mscm* = scutellum; *mtnm* = metanotum; *N* = "neck"; *pa* = parapsides; *PN* = pronotum; *ppl* = pleuron of prothorax; *Te* = tegula; the dotted areas in Vespa represent patches of yellow colouring in the otherwise black notum.

meet in the mid-ventral line. These are the detached pleura of the prothorax, each consisting of episternum and epimeron, and they form one of the characteristics of the Order. Concealed beneath the pleura and associated with them is the prosternum, which will be seen later (p. 180).

(2) In the mesothorax the episternum and epimeron are easily determined by the usual rule.

(3) In the metathorax it has been usual to regard the epimeron as being more or less completely fused with the propodeum but, by following the rule for determining the pleural suture, this view seems to be incorrect. The lower part of the pleural suture is easily traced upwards from the coxal connection

for some distance. The upper part, running down from the pleural-wing-process is, however, not easily recognized. It lies parallel to and almost in contact with the suture between the meso- and meta-pleuron and the upper and lower parts of the suture are connected, about half-way down the side, by a faintly-marked portion running almost transversely across the segment. Thus, the upper part of the episternum has been squeezed out, the lower part of this sclerite being normal and obvious. In the same way, the upper part of the epimeron is distinct and clearly marked off from the propodeum whereas the lower part has been squeezed out.

(4) The Thoracic Spiracles. The 1st lies, as usual, between the pro-

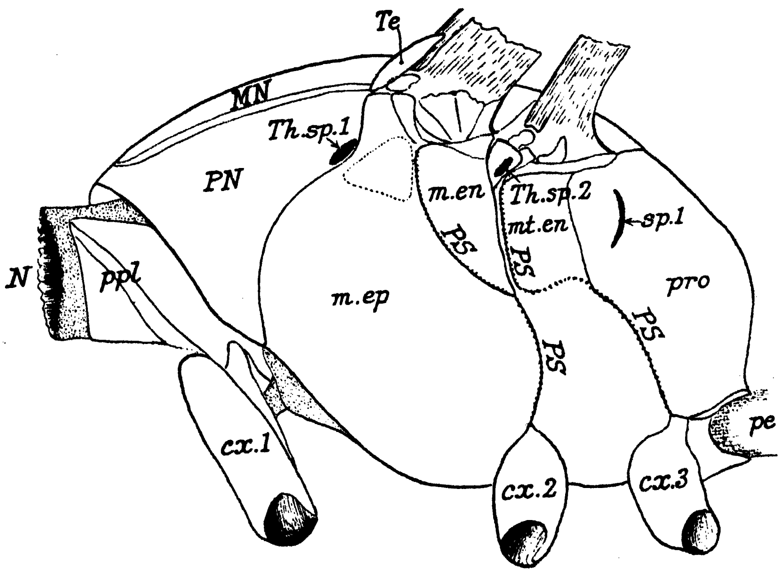

FIG. 109.—Vespa Sp. Lateral view of thorax.

*cx.*1, 2, 3 = the three coxæ; *m.en* = meso-epimeron; *m.ep* = meso-episternum; *MN* = mesonotum; *mt.en* = meta-epimeron; *N* = "neck"; *pe* = pedicel or waist; attachment of second abdominal segment to the first (propodeum) (pro); *ppl* = prothoracic pleuron; *PS* = pleural suture (dotted); *Te* = tegula; *Th.sp* = thoracic spiracle. Note that both thoracic spiracles are beneath the sclerites, so that they are not actually visible until these are lifted. *sp.*1 = 1st abdominal spiracle.

and meso-thorax. The descending part of the pronotum borders the episternum of the mesothorax. This suture, near its upper end, curves so as to produce a hardly-recognizable backwardly-projecting flap. Beneath this flap is the 1st spiracle. (*N.B.*—In Bombus this flap is very large.)

To find the 2nd spiracle, recognize the suture between the pleura of the meso- and meta-segments and, at its upper end, is a small projecting piece of the meso-epimeron. The spiracle lies immediately beneath the posterior margin of this process.

(5) The propodeum (and its curved spiracle) is easily recognized (see Fig. 109).

The Legs. Note the large coxa and the small trochanter, the latter composed of one segment. (*N.B.*—In most of the Hymenoptera Parasitica the trochanter consists of two segments whereas, with only one or two exceptions, in the Hymenoptera Aculeata it has only one.)

Below the trochanter are the femur, tibia and 5-segmented tarsus.

Examine the apex of one of the anterior tibiæ and note the single long, specially modified, spur. On its inner edge it has a strip of membrane.

Note that the base of the long basal segment of the tarsus is hollowed out and along the outer margin of the hollow is a very fine comb of short hairs. The tibial spur and this comb together constitute the "antenna-cleaner," the antenna being drawn between the two and so cleaned. Note that the median and posterior tibiæ have two apical spurs or "calcaria." The presence or absence and the number of these apical spurs, whether one or two, is of systematic importance.

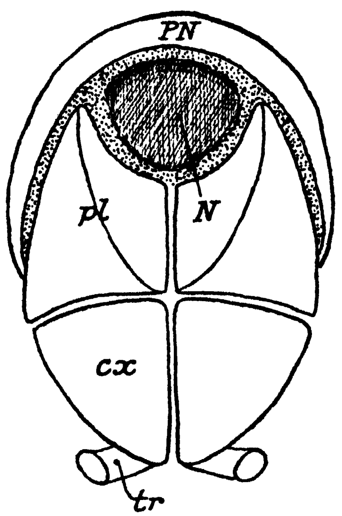

FIG. 110.—Vespa Sp. Front view of prothorax, after removal of head.

cx = coxa; *N* = "neck"; *pl* = pleuron; *PN* = pronotum; *tr* = trochanter.

Examine the tarsal claws and note that they are simple; in the Eumenidæ, e.g. Odynerus, they are toothed, a character which distinguishes the latter from the Vespidæ.

The Wings. Note the peculiar longitudinal folding of the fore-wings, a character which separates Vespidæ and Eumenidæ from all other Vespoids.

Examine the wing-coupling apparatus, consisting of a series of small hooks along the front edge of the hind-wing, just after the Radial Sector has parted from the Radius, and a downturned edge of the fore-wing just inside where the Media 3 + Cubitus + Anal vein reaches the margin. For the wing-venation, see pp. 113, 114.

Ventral Aspect of Thorax. Note, on the neck, a pair of broad plates the ventral extensions of the detached pleura of the prothorax (see Fig. 110). Raise these and the anterior peak of the prosternum will be seen lying beneath them. From this aspect, the prosternum extends backward beneath the large coxæ of the anterior legs. The sutures between the pleura and sterna of the meso- and meta-thorax are very feebly marked. Note the contiguity of the right and left coxæ in all three segments of the thorax.

The Abdomen. Including the 1st, which has become fused with the thorax, the number of visible segments in the female wasp is seven, while in the male there are eight. An examination of the apex of the body will, however, reveal parts of other segments, making up a total of ten, so that,

in the female there are three and in the male two, concealed and reduced segments.[1]

The Abdominal Spiracles. The tergum of segment 2 forms the anterior face of the segment, its lateral borders being almost vertical and the sternum is very small. Note the point where the tergum of segment 3 passes under the posterior edge of tergum 2, just where the sternum of segment 2 becomes visible. A horizontal line drawn forward from this point will pass through the 2nd spiracle.

The spiracle of segment 3 is the easiest of all to find, as it is a little above the lateral edge of the tergum (i.e. it is in the tergum) and a little behind the overlapping border of the 2nd segment. It may be obscured by being situated in a small extension of the black colouring.

Spiracles 4 to 7 are only to be seen by stretching the body and they lie in a line with the points where the posterior edge of the sternum of the previous

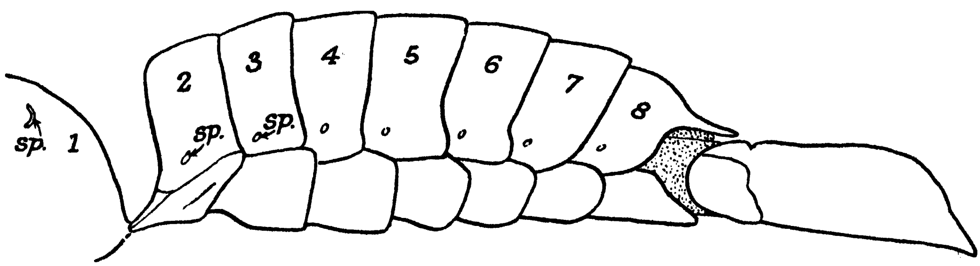

FIG. 111.—Vespa Sp. ♂. Lateral view of abdomen extended after boiling in potash. The apex of the abdomen in a state of rest is shown in Fig. 114 and a detailed description of the apex is given with Fig. 115. The 8 abdominal spiracles (*sp*) are easily recognized.

segment appears from beneath its tergum (see Fig. 111). The 8th spiracle in the female will be seen during the examination of the genital armature.

Cut off the abdomen and boil in strong potash until all the soft parts have been dissolved away.

The Female Armature. (*N.B.*—The sex of the individual is determined by the number of antennal segments, see *ante*, p. 176.)

Projecting from the apex of the abdomen, part of the "sting" will be visible and, in the treated specimen, if this is seized with a pair of fine forceps and gently pulled, segments 8, 9, and 10, together with the armature, will be exposed. The "sting" consists of a pair of fine stylets and a strong median "sheath."

Now carefully cut away all the segments in front of the 7th and then cut out most of it also, so as to expose completely the 8th segment. The most obvious sclerite after this operation will be the large one on each side

[1] It is most unfortunate that systematists mostly refer to the 2nd segment as the 1st, so that the true 8th is described as the 7th.

containing the spiracle and representing parts of the 8th tergum. Note that these "sclerites" are connected dorsally by a very narrow band of chitin (see Figs. 112 and 113).

It has been mentioned previously (see p. 102) that the female armature

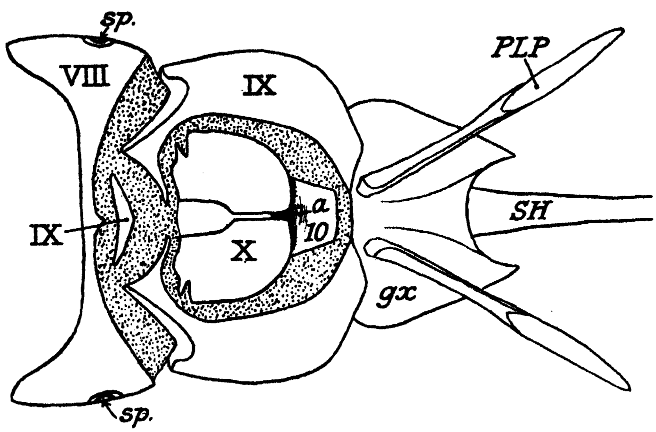

FIG. 112.—Vespa Sp. ♀. The genital armature, dorsal view.
a = anus; *sp* = 8th spiracles; *gx* = gonocoxite; *PLP* = the "palpus"; *SH* = the sheath (part of the sting).

is composed of a pair of structures arising from the 8th sternum and two pairs arising from the 9th. The armature here consists of a pair of stylets, a median "sheath" and a pair of large plates, each of the latter bearing a small 2-segmented palp-like process.

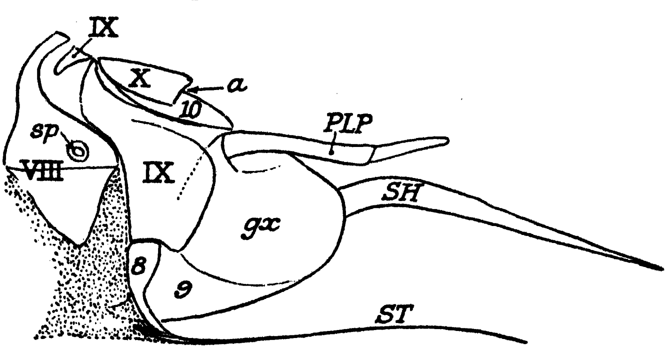

FIG. 113.—Vespa Sp. ♀. Side view of the extended genital armature, after boiling in potash, showing the 8th sternum, bearing the stylets (*ST* is one of them), divorced from its own tergum and attached below the 9th tergum.
a = anus; *sp* = 8th spiracle; *gx* = gonocoxite; *PLP* = the "palpus"; *SH* = the sheath (part of the sting); *ST* = one of the two stylets.

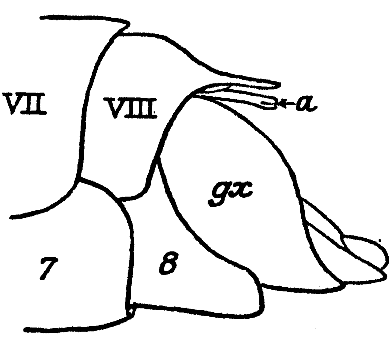

FIG. 114.—Vespa Sp. ♂. Apex of abdomen in a state of rest.
a = anus; *gx* = the gonocoxite (belonging to the 9th segment) with the genital armature partly exposed.

Since the structures arising from the 9th segment must necessarily be inside (or behind) those arising from the 8th, since the 9th segment telescopes within the 8th, it is clear the outermost ventral structures must belong to the

latter segment. Note that the two stylets are the most ventral pair of structures and that, at their bases, they are each attached to an upwardly-projecting more or less triangular plate which is actually attached to the 9th segment, the large lateral sclerite behind the 8th (see Fig. 113). Zander has shown, by following the development of the armature, that these upwardly-projecting sclerites, which are connected ventrally, are the true sternum of segment 8.

The sternum of segment 9, bearing the strong median "sheath," is visible within the 8th and examination will show that it is also attached to the large lateral sclerites of the 9th segment.

Note that these large lateral sclerites extend dorsally and narrow down each to a fine point just before reaching the median line, so that they do not

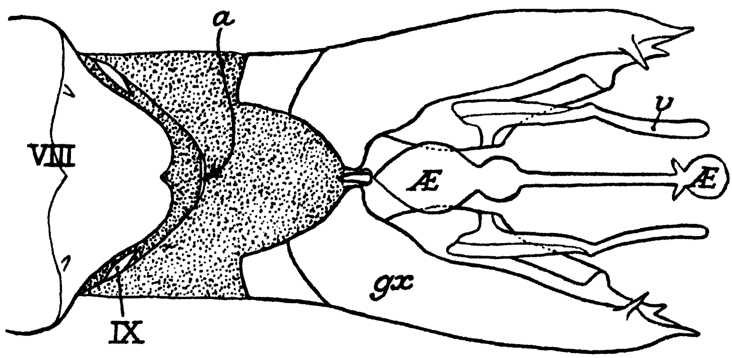

FIG. 115.—Vespa Sp. ♂. The genital armature, dorsal view.
a = anus; *gx* = gonocoxite (appendage of segment 9). The two gonocoxites are known as the "outer valves" and they enclose the "inner valves" or "volsellæ" (*v*), and the "spatha" or ædeagus (*Æ*).

actually join. Behind these points lies a small isolated sclerite and we may take it that this and the large sclerites are the tergum of the segment. Behind each of the large sclerites lies another large plate and attached to each of these plates is the 2-segmented palp-like process already mentioned. These sclerites are obviously the coxites of the 9th segment, the "gono-coxites."

The 10th segment lies above the 9th and between the 8th and the gonocoxites. A small hairy tergum is readily recognizable, beneath which is a thin plate, the sternum, the anus opening between the two (see Figs. 112 and 113).

Examine the structure from the dorsal aspect and draw both dorsal and lateral views.

The Male Armature. This is a compact structure which, as in the female, is almost concealed within the apex of the body when at rest (see Fig. 114). Boil in potash, as before, and extend the armature without breaking it off. Note the comparatively long membranous region between the 8th segment and the armature and note that the anal tube seems to come from immediately beneath the 8th tergum. First examine this tube, noting that, across its base,

runs a narrow chitinous band[1] which is connected on each side with the 8th sternum. This is the 9th tergum. The anal tube, actually the 10th segment, has no tergum, but there is a sternum beneath it.

The sternum of the 9th segment has become completely separated from its tergum and is fused to the base of the armature and is called the "cardo" (see Figs. 115 and 116).

The armature itself consists of a pair of outer lobes or external valves, "stipites," with pointed apices, and to the inner sides of these valves are attached the "volsellæ," thin processes with blunt apices. Between the valves there lies a median structure, the "penis" or "spatha," bearing on each side towards its apex a chitinous "sagitta."

The homologies of the parts. The stipites are obviously the coxites of

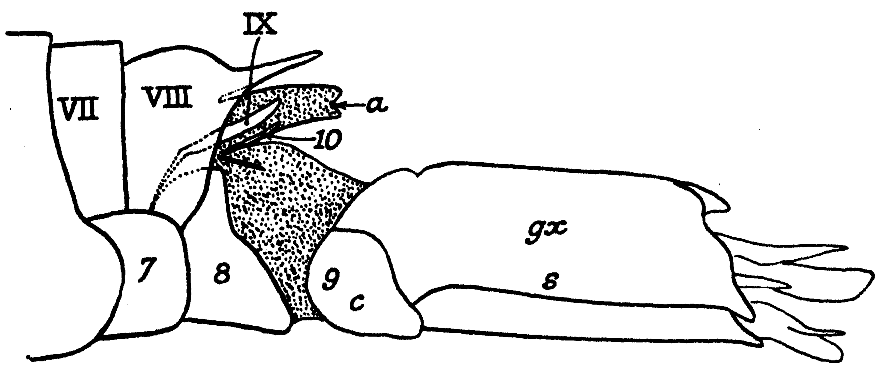

FIG 116.—Vespa Sp. ♂. Lateral view of the apex of the abdomen, extended after boiling in potash. The 9th tergum is shown passing back inside the 8th and attached to the sternum of that segment. To the 9th sternum, completely detached from its tergum, are appended the large gonocoxites (*gx*), beyond which the armature, partly projecting, is indicated.

c = the 9th sternum or "cardo"; *s* = the gonocoxite or "stipes".

the 9th segment. Pruthi (*Q.J.M.S.*, **69**, 1924, p. 84) says that some authors have described the sagittæ and spatha as originating by the splitting of the inner pair of genital buds on the 9th sternum. This makes the sagittæ the homologues of the parameres and the spatha is the ædeagus.

The general similarity between the valves here and in the Lepidoptera is rather striking. Here, as in Triphæna (q.v.), we can recognize the costa bearing the pointed process, the middle part comparable to the valvulæ, and the volsella corresponding to the ventral sacculus (see Fig. 90). It will be seen, on careful examination, that the volsella is attached to an inwardly-bent part of the stipes which might be regarded as ventral.

N.B.—The variation in the form of the parts above described is very great in different Hymenoptera and the student would be well advised to com-

[1] This band is incomplete in some or all species of Vespa, i.e. it is visible on each side but fades away in the mid-dorsal region. It is easily seen in Odynerus.

pare the armature of a Sawfly and of another "wasp," such as Odynerus, with a view to seeing this. Unfortunately also, the names mentioned above are not applied to the same parts by all authors, so that there is a considerable amount of confusion of nomenclature.

In connection with the terminal segments, difficulties arise from the fact that the terms "pygidium," "epipygium" (epipygidium) and "hypopygium" (hypopygidium) are used with different meanings by different authors. The term "pygidium" in insects [1] is used generally to indicate the last abdominal tergum, i.e. the supra-anal (suranal) plate, regardless of which segment it actually is. In Coleoptera, however, it is used in some cases to mean the terminal *visible* segment, the segment immediately preceding it being called the "propygidium."

If "pygidium" is used for the tergum of a segment, one would expect the term hypopygium to refer to the sternum of the same segment but, although it is so used in some cases (see Crampton, G. C., "The Genitalia and Terminal Abdominal Segments of Males, etc.," *Proc. Ent. Soc., Washington*, XXI, 1919, p. 132), many authors apparently agree that it means something different in the male, especially in Hymenoptera and Diptera.

Snodgrass, R. E. (*The Anatomy of the Honey Bee*, Dep. Agric., 1910, p. 73), says that "in many insects . . . the 9th segment often forms a conspicuous enlargement called the hypopygium. . . ."

Crampton (l.c.) uses it deliberately in two different ways as he says that it refers to the entire male genitalia, e.g. in Diptera, or to the plate immediately below the anus in other insects.

Edwards, F. W. ("The Nomenclature of the Parts of the Male Hypopygium of Diptera Nematocera, with special reference to Mosquitoes," *Ann. Trop. Medicine and Parasitology*, 1920, p. 24), wishes to establish the term for the 9th segment and all that follows it "in all but the more specialized metabolic insects."

On the other hand, Bingham, C. T. (*Fauna of British India. Hymenoptera*, I, p. ix), says "the epipygium or dorsal portion of the apical abdominal segment and the hypopygium or ventral portion of the same, together form what is called the pygidium;" and both he and Ashmead, W. H. ("Classification of the Ichneumon Flies, etc.," *Proc. U.S. Nat. Museum*, XXIII, 1901. A table of superfamilies, pp. 2, 3), are apparently using the term as meaning the last *visible* complete segment of the unextended abdomen. In my *Keys to the Orders of Insects*, 1920, I have followed these last authors, but I think it would be better to confine the use of these terms to the last actual segment, the proctiger, naming it the pygidium, the suranal plate the epipygium and the sternum the hypopygium, or else to drop them altogether.

[1] In the Trilobites, pygidium is synonymous with abdomen.

(12) The Hymenopterous Larva

The chief interest in the larvæ of the Hymenoptera is morphological and, unlike the Coleoptera, Lepidoptera and Diptera, little attention seems to have been paid to them from a systematic point of view, except in the case of the Sessiliventres, upon which a volume has been produced by Hachiro Yuasa.[1]

The *Tenthredinid larva* resembles in many characteristics the caterpillar of the Lepidoptera and a comparison of the two should be made, using the description of the caterpillar (see pp. 153–159).

The *Siricoid larva* is a type without prolegs and with reduced or absent thoracic legs, while the larva of the H. Petiolata is a legless grub with well-developed head which is usually colourless like the body and thus affords a simple means of quickly distinguishing the larva from that of many Rhyncophorous beetles.

[1] "A Classification of the Larvæ of the Tenthredinoidea," *Illinois Biological Monographs*, VII, 1922.

IV. SYLLABUS OF A COURSE OF SPECIAL MORPHOLOGY

(two hour periods), worked upon the notes given in Part III

I HAVE set out this Course in thirty practicals, as it was arranged for the Imperial College, but, if it is necessary to limit it to twenty-four periods, the omission of the work on the grasshopper will suffice to produce the required reduction.

There are, as in Part II, some reserves in the preceding notes, such as the dissection of the caterpillar, which will be found useful for those who have extra time to devote to the subject.

1 and 2.	Grasshopper. External characters.
3 to 6.	Dissection of Grasshopper.
7 and 8.	Wing-venation. Diptera.
9 and 10.	" " Hymenoptera.
11 and 12.	" " Lepidoptera.
13 and 14.	The Pentatomid Bug.
15 and 16.	The Cicada.
17 and 18.	The Beetle. External morphology.
19 and 20.	The Beetle-Larva.
21 and 22.	The Moth. External morphology.
23 and 24.	The Caterpillar.
25 and 26.	The Bluebottle Fly (Calliphora). External morphology.
27.	The Dipterous Larva.
28 to 30.	The Wasp and the Hymenopterous Larva.

GENERAL INDEX